DOCTOR OF PHILOSOPHY

Oil Boom, Fiscal Policy and Economic Development

A Computable General Equilibrium Analysis of the Role of Alternative Fiscal Rules In Ghana's Emerging Petroleum Economy

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Mohammed Amin Adam

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University of Dundee

Oil Boom, Fiscal Policy and Economic Development: A Computable General Equilibrium Analysis of the Role of Alternative Fiscal Rules In Ghana's Emerging Petroleum Economy

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Declaration

I hereby declare that I am the author of this thesis and that I have consulted all references cited. All the work, of which this thesis is a record, has been done by myself and has not been previously used for a higher degree.

Signed………………………………

Mohammed Amin Adam, PhD. Candidate

Date ………………………..

Certification

This is to certify that Mr. Mohammed Amin Adam conducted his research under my supervision in the Centre for Energy Petroleum and Mineral Law and Policy (CEPMLP), Graduate School of Natural Resources Law, Policy and Management, University of Dundee. Mr. Adam has fulfilled all the conditions of the relevant Ordinances and Regulations of the University of Dundee for obtaining the Degree of Doctor of Philosophy.

Signed…………………………………

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(Professor of Energy Economics and Policy)

Date…………………………..

Abbreviations

AOE	Additional Oil Entitlement
BIH	Bird in Hand
CAPEX	Capital Expenditure
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CPIA	Country Policy and Institutional Assessment
DSGE	Dynamic Stochastic General Equilibrium
EIA	Environmental Impact Assessment
FDI	Foreign Direct Investment
FPSO	Floating Production Storage and Offloading
FRL	Fiscal Responsibility Law
GAMS	Generalized Algebraic Modeling System
GDP	Gross Domestic Product
GH	Ghana's Fiscal Rule
GHS	Ghana Cedis
GIMF	Global Integrated Monetary Fiscal Model
GMM	Generalized Method of Moments
GNPC	Ghana National Petroleum Corporation
GOG	Government of Ghana
HIPC	Highly Indebted Poor Countries
HPAI	Highly Pathogenic Avian Influenza

IFPRI	International Food Policy and Research Institute
IMF	International Monetary Fund
INSTQ	Institutional Quality Index
IO	Input-Output
LES	Linear Expenditure Systems
MMSCF	Million Standard Cubic Feet
MDGs	Millennium Development Goals
MDAs	Ministries, Departments and Agencies
MDBS	Multi Donor Budgetary Support
META	Mahogany-Teak-Akasa
NOGDP	Non-Oil Gross Domestic Product
NOPB	Non-Oil Primary Balance
PI	Permanent Income
PIH	Permanent Income Hypothesis
PITL	Petroleum Income Tax Law
PNDC	Provisional National Defence Council
PoD	Plan of Development
PSNOPB	Permanently Sustainable non-oil Primary Balance
PSR	Political Risk Services
SAM	Social Accounting Matrix
SIM	Simulation
TEN	Tweneboa-Enyenra-Ntomme
ODA	Overseas Development Assistance

OGM	Overlapping Generations Model
OPEX	Operational Expenditure
UAC	United African Company
UNCTAD	United Nations Conference on Trade and Development
WTI	West Texas Intermediate

Abstract

The objectives of the study are to assess the fiscal sustainability and development impacts of Ghana's fiscal rule for allocating petroleum revenues to the annual budget against alternative fiscal rules - the permanent income and the bird-in-hand rules. Fiscal sustainability is measured by government long-term fiscal space in proportion to non-oil GDP, whilst development impacts are measured through a dynamic CGE model of Ghana.

Generally, the study makes four important findings on how fiscal policy triggered by the inflow of new petroleum revenues could affect the long-term fiscal sustainability and growth of the economy. One, Ghana's fiscal rule is neither fiscally sustainable nor provide higher impacts of petroleum revenues on economic development relative to the permanent income and the bird-in-hand rules. Two, fiscal sustainability does not necessarily lead to greater development outcomes. The bird-in-hand rule is the most fiscally sustainable, but the permanent income rule provides higher development outcomes and can move Ghana's transformation towards a full middle income status. Three, institutional quality in a country could lead to efficiency gains in government spending. Four, efficiency in government spending could improve on development outcomes.

Ghana could therefore benefit from its petroleum revenues by adopting the permanent income rule; and with temporary petroleum revenues, the focus of the country should be on current investment of petroleum revenues in building the country's asset base to support short-term and long-term growth of the economy. However, this should be complemented with strengthening the quality of institutional arrangements to enhance efficiency in government spending.

CHAPTER ONE

INTRODUCTION

1.1 Background

The economy of Ghana has transformed from a low growing economy to a high growing one over the last three decades. The growth of the economy Ghana's economic picked after the Structural Adjustment Program of the mid 1980s, following periods of low or negative growth from the mid 1970s. Since 2001, the economy has grown at an average of 5% per annum (African Development Bank, 2011). In the last five years, Ghana's economy has been among the top performing in Africa, and in 2012 was the fastest growing in the world due mostly to oil exports (International Monetary Fund, 2013). For instance, the country's growth rate increased from 3.7% in 2000 to 8.3% in 2008 and then went down to 4.6% in 2009 (Republic of Ghana, 2010a).

It is fair to say that growth and FDI has increased significantly since the start of the Third Republic. However, there have been major challenges associated with capital shortfalls and fiscal mismanagement in recent times (Aryeetey, 2008). This led to declining growth in 2009 which was partly attributed to the Global Financial Crisis; and even then, the 4.6% growth rate was above the Africa and world averages in that year. Inflation also fell from 40% in 2000 to 11% in 2006 and then went up to 23% in 2009. It stood at 9% as of November, 2011 due to fiscal consolidation and austerity measures (Republic of Ghana, 2010a).

The country's poverty levels have however reduced as a result of the many poverty reduction programmes largely financed by development partners. In 1999, the population below the poverty levels stood at 52% but now stands at 29% which puts Ghana on course to meeting the Millennium Development Goal (MDG) of halving poverty by 2015 (Republic of Ghana, 2009). Ghana is nevertheless far from meeting many of the other MDGs.

Ghana's foreign direct investments increased from US$2 billion in 2009 to US$3.2 billion in 2011, which put Ghana as the third largest recipient of foreign direct investments in Africa following South Africa and Nigeria which received US$5.8 billion and US$8.9 billion respectively (UNCTAD, 2012).

However, the oil wealth is yet to translate into positive development outcomes. Whether expected petroleum revenues from oil exploitation will be a window of development opportunity depends on the prudent and sustainable management of the revenues.

In anticipation of petroleum revenues in the midst of weak institutional capacity for managing large amounts of capital inflows, Ghana requires appropriate fiscal rules to guide allocation of petroleum revenues for budget support to meet her development targets without compromising fiscal sustainability.

Ghana discovered oil and gas in commercial quantities in 2007 and there are concerns regarding the sustainable management of revenues that emanate from the exploitation of these resources.

There have been many studies on the impact of petroleum revenues in the economies of oil producing countries. Most of the studies on resource revenue management have concentrated in the use of either econometric or partial equilibrium models, which leaves out very important variables particularly on the behavior of government and institutions and therefore fail to measure the impacts of more than one policy or external shocks.

They also do not account for the economic interactions between the various markets in a given economy. Further, they ignore important inter-sectoral input-output linkages. Models that analyze economy-wide impact of resource revenues are General Equilibrium (GE) models.

However, Computable General Equilibrium (CGE) models have seen little application in resource revenue management (see Benjamin et al, 1989; Ghadimi, 2007; and Djiofack and Omgba, 2010). In Ghana two recent studies on CGE models, Briesinger et al, (2009) and the World Bank (2010) were focused on fiscal options for managing Ghana's oil windfall. However these studies were done before Ghana chose its fiscal rule expressly articulated in the Petroleum Revenue Management Act 2011 (Act 815).

Further, existing CGE models generally ignore the role of regulatory and institutional arrangements for fiscal management in what has come to be known as absorptive capacity, particularly in assessing the impacts of fiscal efficiency. While Ghadimi (2007) examines the effect of technical absorptive capacity on investments, there has not been a measure of the effect of institutional absorptive capacity in CGE models of resource-rich countries.

This study examines the link between fiscal sustainability and the development impacts of Ghana's fiscal rule against alternative fiscal rules. It also examines the development impact of institutional quality on fiscal rules in the economy. The findings hopefully will guide the government of Ghana on sustainable ways of allocating petroleum revenues for budget support and how fiscal efficiency could enhance the realization of the country's development targets.

1.2 Statement of the Problem

Resource-rich countries that are benefiting from large inflows of resource revenues encounter a number of serious challenges. Resource revenues are subject to high and uncertain price volatility and are likely to destabilize the national budget and consequently lead to liquidity problems (International Monetary Fund, 2007). Natural resources are depletable and the case of intergenerational equity is therefore another challenge.

In addition, the inflow of large resource revenues has negative impacts on the economy and could lead to 'Dutch disease' a situation associated with real currency appreciation and the negative impact on non-resource tradable sector (Ibid, 2007).

The economic performance of most resource-rich countries in the developing world has raised doubts regarding the usefulness of these resources (Wurthmann, 2006). Some have described the phenomenon as 'resource curse' or 'resource-trap' (Mikesell, 1997). Some have attributed this development to institutional weaknesses (Stevens, 2003; Alayli, 2005), corruption and lack of transparency (Wurthmann, 2006). There are many who attribute it to fiscal challenges (Moreno and Rodriquez, 2009). Thus the literature on resource curse shows that it is not the endowment of these resources that is problematic but the management of the resources (Corden and Neary, 1982).

Ghana's economy is faced with fiscal challenges which are likely to be aggravated with expected petroleum revenues. For some time, excessive spending has been the bane of the economy. Especially during election years, government has often resorted to high consumption spending rather than capital spending whiles capital projects are usually misguided with little impact on the economy. These have led to high deficits, high inflation and crowding out of the private sector regarded as the engine of economic growth (Osei and Donfe, 2008). This phenomenon has historical roots also in resource-rich countries that are currently facing serious developmental challenges. For example, during the 1970s oil boom, resource-rich countries resorted to overspending, financing of overambitious projects whiles some even went borrowing against oil resources (Karl, 1997). With petroleum revenues coming into the economy, the temptation for Ghana to continue its excessive spending is very high since most of the factors that account for such spending are still a feature of the economy.

Another challenge results from the recent global financial crisis which increased capital scarcity to developing countries. Several developing countries who went to the capital market during the pre-crisis period for development financing have returned to the International Financial Institutions such as the World Bank and the International Monetary Fund as a consequence of the crisis. For instance, Ghana before the financial crisis raised US$750 million from the capital market through its Jubilee bond. The country even weaned itself from the International Monetary Fund. However, it has now gone back to the IMF for development financing leading to a budget support programme of about US$1 billion for three years starting from 2009; and to the World Bank for US$300 million support in 2009. But this is at a huge cost to the country due to the accompanying conditionality such as public sector employment freeze and divestiture of national strategic assets.

Before this development, Ghana had received significant debt reliefs of more than US$4 billion due to the Highly Indebted Poor Countries (HIPC) initiative which decreased its debt vulnerability and strengthened debt sustainability. With expected petroleum revenues, overseas development financing is likely to scale down (International Monetary Fund, 2009) whiles the country continues to suffer from the effect of the global financial crisis. In Section 5 of the Petroleum Revenue Management Act 2011 (Act 815), government is allowed to collateralize petroleum revenues. This already demonstrates Ghana’s debt vulnerability within the medium term when petroleum revenues begin to fall and in the long-term when the revenues are depleted (World Bank, 2010) and may also weaken its debt sustainability bringing it to its pre-HIPC status.

In 2011, Ghana's parliament passed the fiscal model for managing petroleum revenues through Act 815. The fiscal rule requires that not more than seventy percent of the annual "Benchmark Revenue" from petroleum receipts should be spent through the national budget and the balance saved in the Ghana Petroleum Funds. "Benchmark Revenue" is defined as total annual petroleum revenue net of the equity financing costs of the national oil company and not more than 55% of the remaining carried and participating interest (both allocated to the Ghana National Petroleum Company). The fiscal rule was neither based on any analysis of its long-term sustainability nor of any empirical assessment of its development impacts.

Apart from the lack of empirical foundation of Ghana's fiscal rule, the country is further associated with the problem of low absorptive capacity due to weak institutions, non-adherence to budget institutions and the inability to invest large inflows of expected petroleum revenues efficiently, which would likely affect development outcomes (Ghana Aid Effectiveness Forum, 2010). These institutional problems could affect the transformation of petroleum revenues to economic growth and development. The literature on resource curse confirms that the growth performance of resource-rich countries is primarily the result of how resource rents are distributed through institutional arrangement (Eifert et al, 2006).

Both the World Bank and the International Monetary Fund estimate that Ghana would receive annual average revenues of US$1 billion at crude oil price of US$75 per barrel for 20 years from the first phase of the Jubilee operations. This is expected to extend beyond the stated period as many discoveries have been made apart from the Jubilee fields.

Ghana's fiscal rule seeks to allocate new revenues from oil to the budget. Theoretically, an increase in government revenues from additional sources would lead to increased government spending. However, with expected short petroleum revenue horizon, the questions that should be confronted by Ghana is whether its fiscal rule can achieve fiscal sustainability, and whether it can have greater development outcomes on the economy.

Also, there is concern about fiscal efficiency and whether the effect of Government expenditure on development could be enhanced with improved spending efficiency resulting from improved institutional quality. Resource-rich countries are always confronted with the difficulties of how much to spend of their resource revenues and the efficiency of spending; and its contribution to avoiding the resource "curse", the situation Ghana is faced with at the moment.

The objectives of the study are therefore threefold –

a. To assess the fiscal sustainability of Ghana's Fiscal rule in comparison with other alternative rules;
b. To assess the development impacts of Ghana's fiscal rule in comparison with other alternative rules; and
c. To assess the development impacts of fiscal efficiency of fiscal rules.

1.3 Research Questions

To accomplish the objectives of the study, the study seeks to answer the following questions.

a. To what extent is Ghana's fiscal rule for allocating petroleum revenues to the budget more fiscally sustainable relative to other alternative rules?
b. Does Ghana's fiscal rule have higher development impacts relative to other alternative rules?
c. To what extent can institutional quality affect the development impacts of fiscal rules?

1.4 Methodology

To answer these questions, three levels of analyses have been conducted. The first analysis uses simple fiscal sustainability measures to explain the sustainability of alternative fiscal rules. In the second analysis, a dynamic CGE model built for Ghana is used to analyze the development impacts of fiscal rules. In the third analysis, the development impacts of institutional quality are measured by the introduction of an institutional quality index in the CGE model.

Fiscal sustainability analyses focused on comparison between Ghana's rule against alternative rules – the Permanent Income (PI) rule and the Bird-in-hand (BIH) rule, by computing and analyzing the most sustainable fiscal balance among them. The PI and BIH rules are examined because they are the most commonly used fiscal rules in resource-rich countries.

The CGE model follows the model developed by Logfren et al, (2002) to analyze the economy-wide effects of policies in developing countries. The Mathematical presentation of the model is adopted from Briesinger et al, (2011) but has been modified to capture institutional quality considerations to address the objectives of the study.

The model describes the behavior of all economic agents. On the supply side, it assumes constant-returns to scale technology with constant elasticity of substitution (CES) aggregation function between primary inputs. There are three primary factor inputs in our model; labour, capital and land. There are also intermediate inputs required to produce each sector's output. For the substitution between primary and intermediate inputs in the production functions, we assume a Leontief technology.

For commodities that are sold domestically and for exports, a Constant Elasticity of Transformation (CET) function is applied, while for commodities that have both domestic and foreign supply, an Armington Constant Elasticity of Substitution (CES) is used.

Labour is mobile across sectors but capital is fixed. An important assumption in the model is full-employment. In this model we further assume a diminishing marginal efficiency of investment due to the problem of absorptive capacity and incorporate costs of adjustment for capital stock and institutional quality index. The World Bank's Country Policy and Institutional Assessment (CPIA) index is used as proxy for institutional quality. The CPIA reflects a measure of four clusters of policy and institutional environment which varies across countries. The institutional quality index is introduced into the CGE model as a measure of efficiency in the policy and institutional environment for managing petroleum revenues, whilst the assumption of diminishing marginal efficiency of capital captures the effect of inefficiency on economic growth.

On the demand side, household consumption is allocated across different commodities (market and home commodities) in line with Linear Expenditure System (LES) demand functions, solved from maximization of a Stone Geary utility function. On the government side, a Cobb-Douglas aggregator function with endogenous taxes is assumed. Savings and Investments are endogenously determined. In the foreign sector, commodities are tradable but capital and labour are not. Another important assumption in the model is the small open economy assumption such that the country does not have influence on world prices of imports and exports. The exchange rate is flexible.

The model is calibrated to the updated Ghana 2007 Social Accounting Matrix (SAM) used in Briesinger et al, (2011). The SAM has information covering demand and production structures of 70 detailed sectors, comprising of 27 agricultural subsectors, 33 industrial subsectors, and 10 service subsectors. There are two types of households (urban and rural); three factor inputs – labour, capital and land. Capital is sector specific and labour is mobile across industries.

In all, 7 policy simulations have been conducted based on 2 main scenarios. The first scenario assesses the development impacts of Ghana's fiscal rule against alternative rules and the second scenario assesses the development impacts of fiscal efficiency.

1.5 Justification and Contributions of the Study

Fiscal rules by themselves are not sufficient to ensure sustainable development impacts. They address the question of how much to spend but ignore the efficiency of spending. Fiscal rules must therefore be complemented with the institutional arrangements that make spending efficient. Ghana is however associated with weak institutions (World Bank, 2009) and whether its fiscal rule would increase the development impacts of petroleum revenues can be measured through empirical examination.

Political and institutional arrangements are the most important determinant of how countries with oil perform (World Bank, 2009). The difference in the growth performance of resource-rich countries is primarily the result of how resource rents are distributed through institutional arrangement (Eifert et al, 2006) and countries that ignore the importance of these arrangements and have weak institutional environment will likely see their oil resources turned into a curse (Eifert et al, 2002). Also, Ross (1999) identified three reasons why policies have failed in countries confronted with development challenges and associates the phenomenon to the policies dictated by short-sightedness and excessive spending, the influence of interest groups and lack of accountability as a result of the state not imposing taxes on people and depending on resource rents.

Models of computable general equilibrium applied to fiscal rules in resource management excludes efficiency measures such as the quality of institutional arrangements (for example; Benjamin et al, 1989; Decaluwé et al, 1990; Ghadimi, 2007; Omgba and Djiofack, 2010; Briesinger et al, 2009; World Bank, 2009).

This is confirmed in Söderbaum (2000) who observed that the theoretical framework of computable general equilibrium combines general equilibrium theory, neoclassical micro-economic optimization behaviour of rational economic agents, as well as some macroeconomic features to explain economic, social and environmental policies, but they fail to account for the effects associated with "institutional arrangements, ethical issues and the developmental needs of a society within an interdisciplinary, pluralistic, holistic, and dynamic approach".

Also, in spite of the recent attempts at introducing dynamic features into CGE models, these are limited in scope and form. For instance, the models that account for capital accumulation as a dynamic process is very silent on regulatory and institutional changes that an economy needs to be on the desired path to steady state equilibrium. The lack of incorporation of these dynamic features narrows the economy to an "artificial perfect macroeconomic stability" (Ackerman, 2005), which inadequately explains the adjustment path to equilibrium.

The limitations of CGE models in relation to the efficiency of fiscal rules is an important gap that need to be addressed. Further, existing CGE models on Ghana's fiscal rule do not incorporate efficiency features, thus ignoring the impact of the efficiency of fiscal rules on economic development.

The study attempts to address these shortcomings by making four major contributions to the literature on CGE models and build on existing frameworks in Ghana.

a. It seeks to explore the relationship between fiscal sustainability and development outcomes, a phenomenon that has not been established.
b. It incorporates efficiency features associated with institutional quality in a CGE model to address a major weakness of CGE models in adequately accounting for the adjustment path in a dynamic process.
c. It is the first empirical analysis of Ghana's fiscal rule for managing its petroleum revenues. The Ghana rule is provided for in the Petroleum Revenue Management Act 2011 (Act 815).
d. It adds to the exiting literature on modeling in Ghana and increases options for policy analysis in the development process of the country.

1.6 Organization of the Study

The study is structured as follows: Chapter 2 deals with the current state of fiscal management in Ghana and future trends. Chapter 3 covers literature review whilst Chapter 4 provides estimated petroleum revenues. Chapter 5 deals with analysis of fiscal sustainability of fiscal rules, comparing Ghana's rule with alternative rules – the Permanent Income and Bird-in-hand rules. Chapter 6 describes the CGE model for Ghana and analyzing the theoretical foundations of CGE models and the main features of Ghana's SAM, the data set to which the model has been calibrated. Chapter 7 presents analyses of policy simulations. Chapter 8 summarizes the findings and conclusions as well as limitations of the study and some recommendations.

CHAPTER TWO

THE CURRENT STATE OF FISCAL MANAGEMENT IN GHANA AND FUTURE OUTLOOK

2.1 Introduction

This section explores Ghana's macroeconomic environment particularly the fiscal framework and its management. It also analyzes the short-term and long-term policy issues confronting Ghana as a result of expected petroleum revenues, and how the political economy could affect the fiscal policy and the effective use of petroleum revenues. Ghana is confronted with important policy questions as it transitions into a major oil producing country including issues such as crude oil price volatility, and fiscal sustainability.

2.2 Fiscal Management with and without Petroleum Revenues

2.2.1 Fiscal Management before the Onset of Petroleum Revenues

Ghana's record of fiscal management over the last two decades showed an economy which was vulnerable to external shocks, which destabilized the economy. As a country dependent on primary commodities of gold, cocoa and timber, the country's finances have not been stable due to volatilities in the prices of these commodities.

As a result of these challenges, the economy has been associated with serious fiscal problems including fiscal deficits, and poor trade balances. Recent reported poor fiscal management led Fitch Ratings to downgrade Ghana's financial outlook from stable to negative in 2009. With uncertainty over petroleum policy and poor fiscal management, Standards and Poor's also downgraded Ghana in 2010 from B+ to B. The rating in 2011 was not different.

The causes of these fiscal challenges are not far- fetched. Fiscal management has been the major problem for the economy largely arising from excessive expenditures to meet the development commitments of the country. These have been compounded by high election year spending as a result of the desire to retain political power by the governing party. For example, the election years of 2008 and 2012 recorded 14% and 12% of GDP in fiscal deficits respectively.

It must be noted that government revenue over the years has been increasing steadily since 2000 with the revenue/GDP ratio increasing from 17.7% in 2000 to 26 percent in 2007, a trend mirrored by the increase in tax revenue, largely attributed to increasing efficiency, widening the tax net and an increase in the average indirect tax rate, but the rate and size of public spending have not been controlled over the years (Republic of Ghana, 2010a). Since 2007, the fiscal downturn resulted from increased government spending, including the spending of US$750 million raised from the capital market on budget support contrary to the intended use for the facility (Ibid, 2010a).

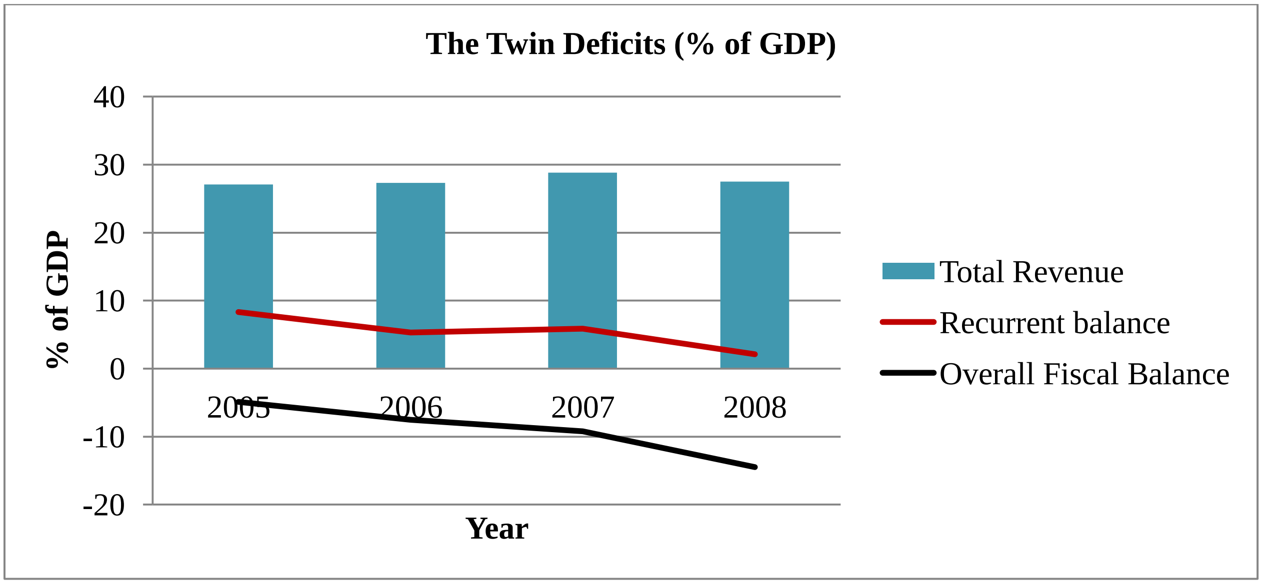
It is also important to note that there are developments on the global scene with regards to oil imports, food and energy sector problems. High crude oil prices in 2007, high food prices, and energy subsidies affected economic performance although not as bad as what other developing countries experienced. As a result of this, the macroeconomic gains of the period between 2001 and 2007 were eroded with inflation rising to 19%, foreign reserves weakened from US$ 2.8 billion down to US$ 1.9 billion, and interest rates increasing from 10 to 25% (Bank of Ghana, 2010).

The Government of Ghana set a fiscal framework to reduce fiscal deficits from 14% in 2008. Through inflation targeting monetary policy and fiscal adjustments with increased domestic revenues, the deficit was reduced to 9.4% of GDP in August 2010, but this reduction could not be sustained as 2012 produced a higher deficit of 12% of GDP.

As indicated above, the rise in fiscal deficits can largely be attributed to higher public expenditures over the years which reached 41% of GDP in 2008 from 37% in 2007 and 34% in 2006, resulting from spending on increased public wages, energy subsidies, debt service and capital expenditures. For instance, the public sector wage bill increased from 8.5% to 11.3% of GDP between 2005 and 2008 (World Bank, 2010).

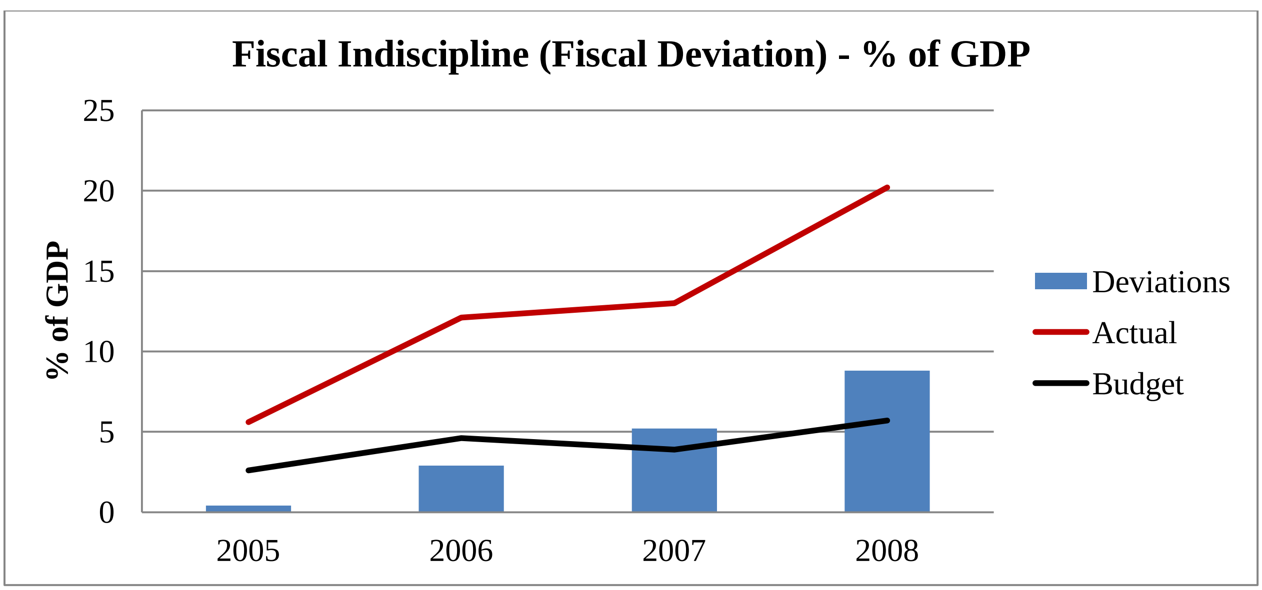
Apart from the fiscal deficits, the current account deficit also widened by US$1.2 billion in 2008 to around 18% of GDP, which was largely due to non-oil imports which grew by US$1 billion in 2008 from US$6 billion in 2007 (Republic of Ghana, 2010a). Between 2009 and 2011, the recurrent balance declined to an average of 9% of GDP due to increased exports arising from oil and cocoa exports. In 2011, oil production was 24,451,452 barrels rising from 1,181,088 barrels in 2010 (Republic of Ghana, 2012). However, oil imports have also continued to influence the balance of trade and the budget. This led to postponement of planned increases in the prices of petroleum products whiles petroleum subsidies which characterized the period reached 2.4% of GDP in 2008. But these measures eventually exposed the weaknesses in the fiscal system resulting in a huge fiscal deficit of 14% of GDP by the end of 2008 with its negative consequences on macroeconomic stability (see Figures 2-1 and 2-2).

Figure 2-1: The Twin Deficit position



Source: International Monetary Fund, Ghana Article IV Consultations, IMF Country Report, 2009).

Figure 2-2: Fiscal Deviations



Source: International Monetary Fund, Ghana Article IV Consultations, IMF Country Report, 2009).

The financial deficit in the public sector has serious consequences for inflation and public debt management, especially through budget deviations, including wiping out private savings and investments. The deficits absorb all the savings coming from outside the country as well as those mobilized domestically. This has often denied the private sector access to credit and therefore the ability to take advantage of economic expansion opportunities.

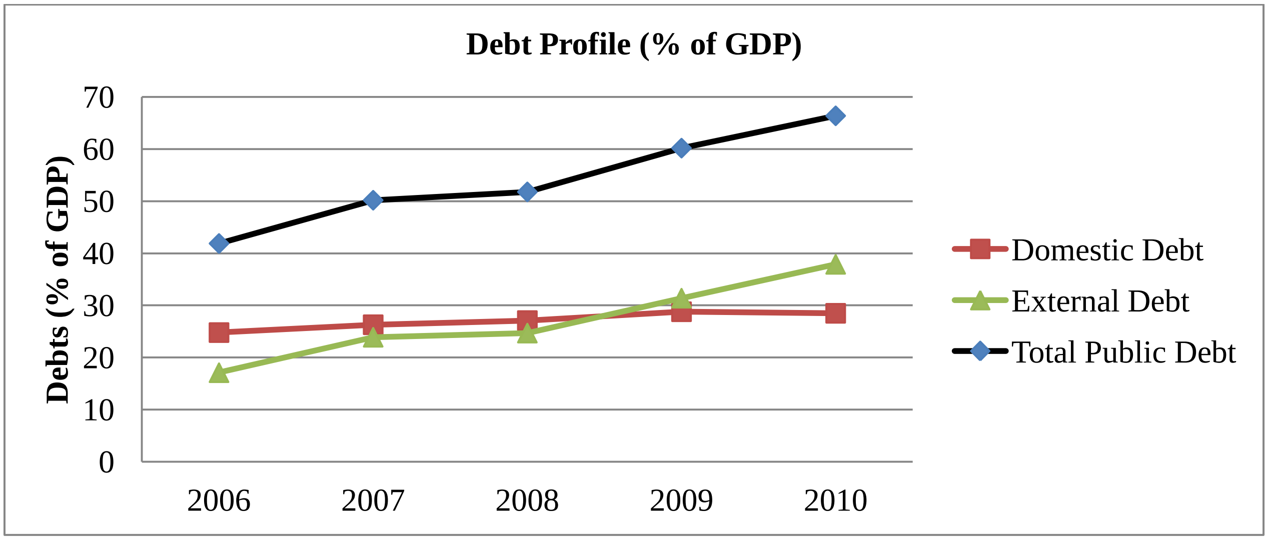
The World Bank has observed that if Ghana is to maintain an average GDP growth of 6% per annum, then the public sector deficit must be addressed to raise aggregate investments rate between 2% to 4.5% (World Bank, 2010). The Government of Ghana and the Bank of Ghana are sponsoring a new legislation, the Fiscal Responsibility legislation, to inject fiscal discipline by imposing limits on the fiscal framework. Whether this legislation will solve the practical difficulties of fiscal deficits has not been examined in detail yet.

Another fiscal challenge the economy has been facing is government's management of public debts. Government strategy for debt management especially domestic borrowing has not responded to the growing development of the financial sector. The fiscal and current account deficits exposed the increasing demand for financing. This has been difficult since divestiture proceeds which have largely been used to finance deficits are no longer coming in. In fact, the twin deficits of 2009 and 2010 were financed from the divestiture of Ghana Telecom to Vodafone, the balance of the Eurobond issued in 2007, international reserves and domestic short-term borrowing.

The financial situation of the country has increased its debt vulnerability and debt levels are likely to reach unsustainable levels with its negative implications for international reserves, and the strength of the Ghanaian Cedi. The global financial position following the financial crisis and the economic downturn has further increased the debt vulnerability. Foreign Direct

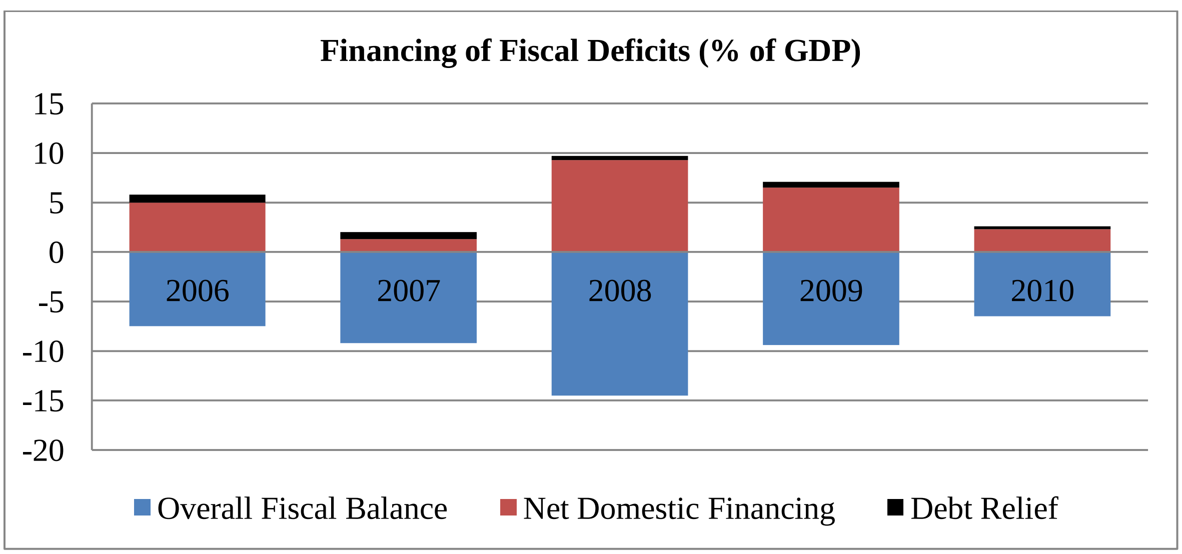
Investments are lower, external demand for Ghana's exports and remittances have also gone down due to the economic downturn in Europe and the United States. This qualifies Ghana among the countries that are most vulnerable (World Bank, 2009).

Figure 2-3: Ghana's Debt Profile (2006 – 2010)



Source: Republic of Ghana (2008, 2009, 2010, 2011), Budget and Policy Statements.

Figure 2-4: Domestic Debt Financing



Source: Republic of Ghana (2008, 2009, 2010, 2011), Budget and Policy Statements.

From Figures 2-3 and 2-4, Ghana's debt profile before the rebased GDP showed that domestic debts were on the high side due to delays in repayment of domestic debts, high domestic financing of fiscal deficits and debt reliefs. However, external debts overtook domestic debts following Ghana's discovery of oil, which did not only improve debt sustainability but also raised the country's credit worthiness.

In addition to these challenges in Ghana's fiscal management, the issue of fiscal efficiency has undermined the contribution of fiscal management to improving the public financial management system and national development for that matter. A fiscally challenged country must be concerned about fiscal discipline and efficiency. A country can achieve fiscal expansion, fiscal sustainability and intergenerational equity; and yet unable to transform its oil wealth into development. Fiscal efficiency is therefore an important requirement to ensuring that petroleum revenues do not go to wasteful public spending.

At the core of fiscal efficiency is a sound public financial management system, which has equally been constrained necessitating several reforms in Ghana for enhancing efficiency, accountability and transparency in the financial management functions of government. This has focused on budget preparation, budget implementation, accounting, cash management, aid and debt management, revenue management, procurement and auditing.

In spite of these reforms, public financial management has not improved. The External Review of Public Financial Management (World Bank, 2006) also recognizes that "budget information is of poor quality, information on planned expenditures diverges from actual and its presentation is not reader friendly to anyone other than budget experts". Another External Review of Public Financial Management (World Bank, 2009) further notes that the budget process is highly fragmented, and only less than 45% of expenditure is covered by the Medium

Term Expenditure Framework; budget ceilings are less credible and are often ignored by the implementing agencies, the Ministries, Departments and Agencies (MDAs).

The consistent occurrence of deviations from budget targets and the widening fiscal deficits expose the weaknesses in the public financial management system. With petroleum revenues expected into the economy and largely through the budget, the challenges will get worse. Petroleum revenues will not bring relief to the economy if the efficiency of spending and transparency are not enhanced.

2.2.2 Fiscal Outlook with Petroleum Revenues

The period before the onset of petroleum revenues was characterized by large fiscal deficits, fiscal indiscipline, and high debt levels. The fiscal outlook with the inflow of petroleum revenues depends to a large extent on how these challenges can be addressed.

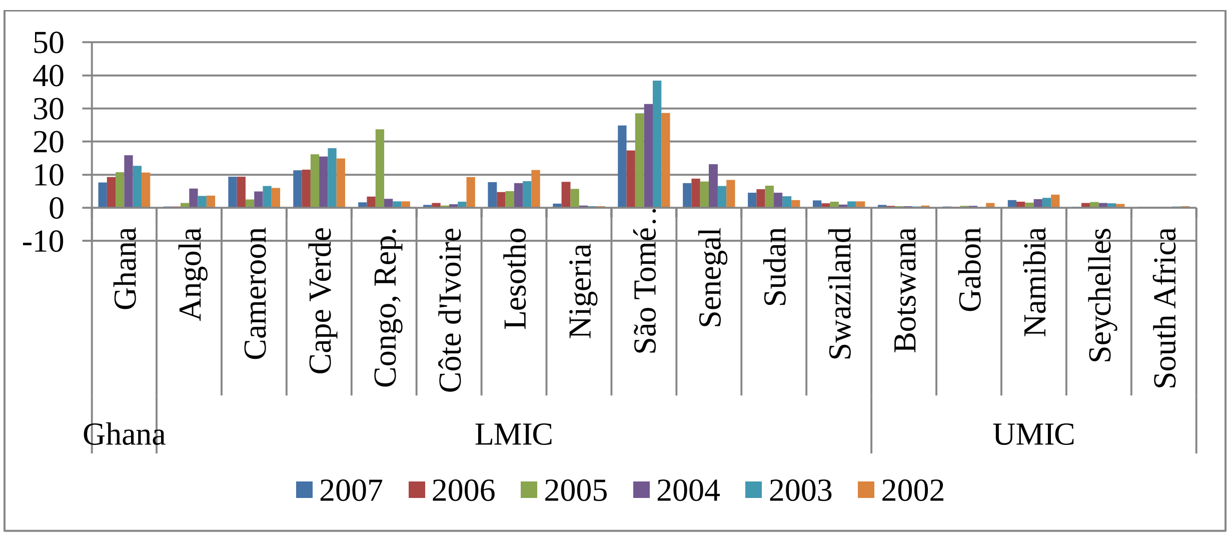
Between 2009 and 2011, Government fiscal deficit averaged 9% of GDP and is expected to decline to 6% of GDP in 2015 (International Monetary Fund, 2013). This is however doubtful considering that the deficit level in 2013 stood at 10.8% of GDP and 11.8% in 2012 (Government of Ghana Official Portal, "Budget Deficit of 10.8 Per cent Recorded In 2013 –Bank of Ghana", 3 April, 2014). The implementation of the new Single Spine Salary Structure has further widened the public wage bill by 47% between 2011 and 2012 in nominal terms.

The International Monetary Fund (2013) further predicts that the current balance could increase to 11.9% of GDP in 2014 notwithstanding that oil production is likely to peak during this period with oil exports growing. This could be due to the rising imports of consumables, an important feature of "Dutch" disease. Petroleum revenues are temporary and may not be able to support future sustainable development. Apart from this, the fiscal challenges are unlikely to improve due to the following reasons.

Debt levels are expected to increase as a result of increased borrowing against expected petroleum revenues. Ghana has already legalized collateralization of petroleum revenues and contracted a US$3 billion loan from the China Development Bank on the back of petroleum revenues. This is in additions to a Jubilee Bond of US$750 million whose repayment is due in 2017. The country's debt profile is estimated to have increased by 65% in two years starting 2009 from US$8.1 billion in December 2008 to US$13.4 billion in May, 2011(The Statesman, Ghana's Debt has Doubled, 1st July, 2011).

The developments on the debt front is further compounded by uncertainty regarding Official Development Assistance (ODA). ODA is likely to scale down as a result of expected petroleum revenues. Ghana's history of ODA and aid flows witnessed a rising trend from 2002 to 2004, but declined consistently thereafter between 2005 and 2007. However, this trend holds for many other developing countries except a few as could be seen from the following Figure 2-5.

Figure 2-5: Trends in ODA and Aid as a percentage of GDP

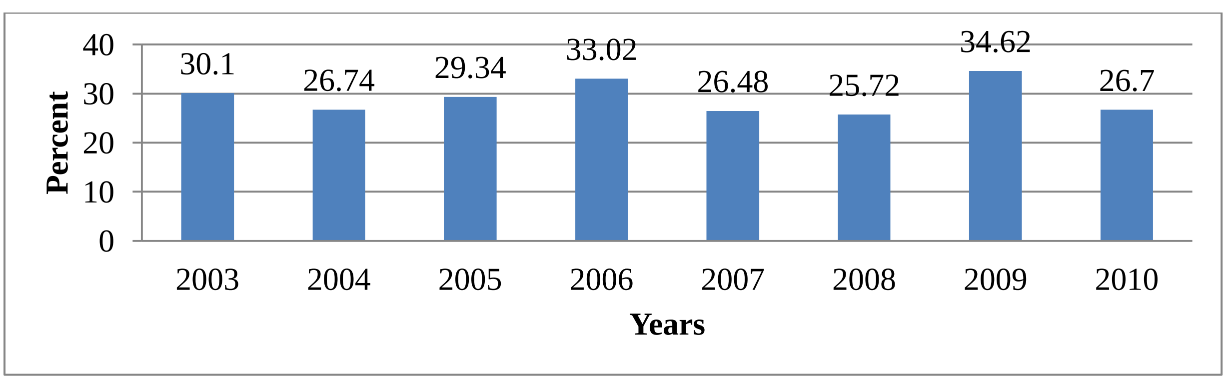


Source: World Development Indicators (2009)

The common observation in the trend of ODA inflows is the inverse relationship between a country's net flow of ODA and its level of economic development. Thus, countries such as Ghana, Cape Verde and South Africa that have made significant progress in economic development have experienced a decline in development assistance. Ghana has been declared a lower middle income country, and with more petroleum revenues expected to flow in to the economy as production of oil increases, there is possibility that official development assistance will fall.

Another source of development assistance to Ghana which will likely fall further is in the area of budget support through the Multi Donor Budget Support (MDBS), a programme requiring donors to pool resources together for harmonizing development support to Ghana. Official statistics show that the MDBS contributed more than US$2 billion in budget support since its inception in 2003 and has constituted about 30% of total donor inflows to the country (Ministry of Finance and Economic Planning, 2010). There however has been some volatility in MDBS support which has likely introduced some instability in the budget as demonstrated in the consistent fiscal deficits recorded over the same time. The following Figure 2-6 shows the status of MDBS inflows to Ghana.

Figure 2-6: MDBS Contribution as a percentage of total aid to Ghana



Source: Ministry of Finance and Economic Planning

Low ODA inflows coupled with low Foreign Direct Investments will likely bring about a decline in real economic growth. Thus, production of oil in Ghana and the expected revenues from oil does not only provide the economy a financial relief but also threatens economic performance.

Debt vulnerability is likely not to get better in spite of the petroleum revenues. A Preliminary Debt Sustainability Analysis conducted by the World Bank based on Ghana's debt profile through December 2008 and the macroeconomic framework for 2009 – 2011, recommends that there will not be significant change in the medium-term risk of debt distress; and this has been confirmed by an updated debt sustainability analysis which shows a rise in debt distress (International Monetary Fund, 2013). Moreover, the attempt to borrow on non-concessional terms against future oil revenue for purposes of posting fiscal consolidation would further worsen Ghana's risk of debt distress. The large fiscal deficits the country records now are also likely to take Ghana to unsustainable debt levels.

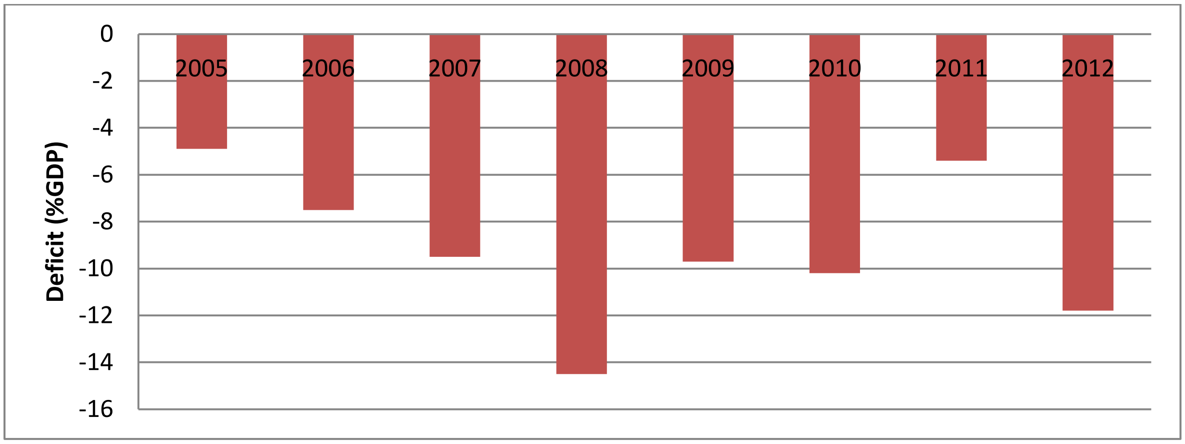
However, at current debt levels, the export of oil and inflow of petroleum revenues will improve Ghana's debt sustainability if production levels increase beyond the peak jubilee volume of 120,000 barrels per day. Both the solvency and liquidity ratios show that debts in proportion to total revenue ratio and debts in proportion to GDP will be reduced indicating that Ghana could borrow more. This is complemented by the rebasing of the GDP which saw a significant rise in the country's GDP. However, when pegged against the pre-rebased GDP, Ghana could be heading to its pre-High Indebted Poor Country (HIPC) debt position, spelling fiscal dangers for the economy.

If Ghana is to improve on its fiscal outlook, there must be serious efforts at improving on tax collection and controlling public spending but this requires higher institutional quality to achieve. This is also consistent with recent recommendations made by the World Bank to the Government, which asked the Government to raise tax collection, reduce expenditures and ensure that expenditure cuts do not fall disproportionately on public investments in order to protect wages, salaries and other important recurrent cost (World Bank External Review, 2009). This was to ensure that fiscal measures did not adversely affect growth substantially with its implications for poverty reduction. Government should also correct the country's twin deficits problem if petroleum revenues will translate in to sustainable development.

Following the global financial crises and decline in foreign resource inflows, Ghana needed fiscal space to meet its development targets. Fiscal space refers to the 'availability of budgetary room that allows a government to provide resources for a desired purpose without any prejudice to the sustainability of a government's financial position' (Heller, 2005). Judging by this, the inflow of petroleum revenues in 2011 was timely though not sufficient to provide the space fully at least for the year.

Government also became overambitious with its development programme due to the expected petroleum revenues, which worsened its fiscal position for 2011. Government's expected fiscal deficit for 2011 had been projected at 5% of GDP, but this was revised to 7% of GDP in the Supplementary Budget in spite of the entry of petroleum revenues in the budget. Also, fiscal deficit rose sharply in 2012 attributed to subsidies, low disbursement of grants and shortfall in petroleum receipts (Republic of Ghana, 2013). The fiscal performance of the Government of Ghana is presented in Figure 2-7.

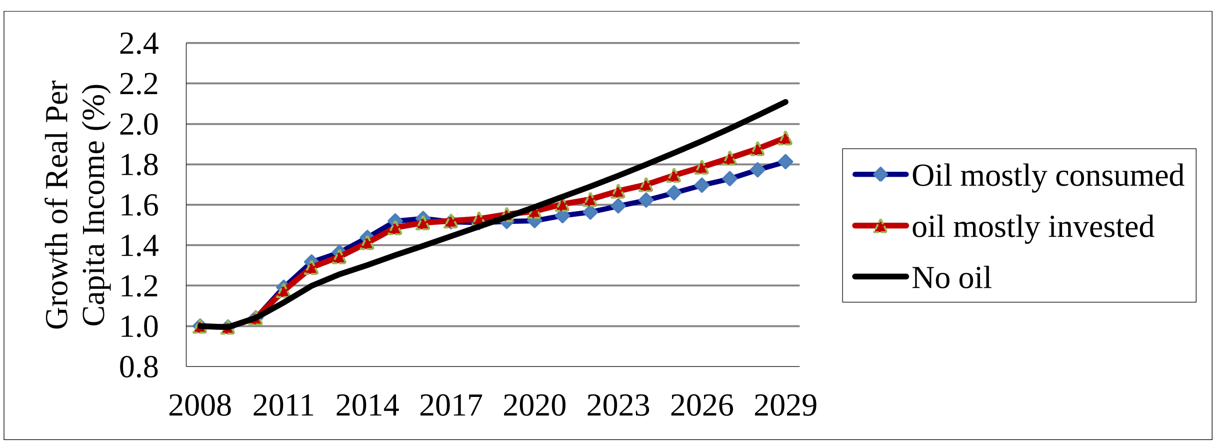
Figure 2-7: Ghana's Fiscal Performance (2005 – 2012)



Source: Republic of Ghana (Various Budget Statements, 2006 – 2013).

The problem associated with weak institutional infrastructure could undermine the development effects of efficient fiscal management. For instance, in a study by the World Bank (2009), investment of petroleum revenues within the current status of weak public financial management will not bring improvement in the living conditions of the people. As in Figure 2-8 below, investments of petroleum revenues could lead to lower per capita incomes in the long-run compared to a higher per capita income in a non-oil economy.

Figure 2-8: Real Per Capita Income in Ghana with oil Revenues



Source: World Bank (2009b) *Economy-wide impact of oil discovery in Ghana*, Report No. 47321-GH, November 30, 2009. PREM 4 Africa Region.

Important reforms are a necessary requirement for improved public financial management and investment efficiency for that matter. The government introduced a new legal framework, the Financial Administration Act, aimed at strengthening public financial management. Government has also enacted a Petroleum Revenue Management Act, and reduced the powers of the Minister of Energy under a new Petroleum Commission Act 2011 (Act 821).

The new legal reforms have also avoided the conflict of interest in the role of the National Oil Company, the GNPC (which hitherto performed its commercial functions and regulatory functions delegated by the Minister of Energy). A new regulatory regime has been introduced by an Act of Parliament, the Petroleum Commission Act, setting up an independent regulator of petroleum operations covering upstream regulations including evaluation of applications for petroleum licenses. However, the implementation of the Act as well as other reforms has been ineffective so far because the Legislative Instruments that are required to give effect to the new laws are not yet in place.

There is no doubt that the public financial management system in Ghana is faced with challenges. Some of the challenges are that; institutions are non-compliant with statutory regulations and penalties are not enforced. There are also delays in processing payments for contractors engaged by government for goods and services and non-timely preparation and submission of withdrawal applications to the World Bank for the releases of funds.

One serious development challenge that has characterized public financial management in most developing countries is poor governance of resources and corruption due to low institutional absorptive capacity. This phenomenon is what is described as institutional causality of “resource curse” (Sala-i-Martin, 1997). This could increase social, economic and political inequalities in a country (Gupta et al, 1998), lower economic growth and undermine economic development (Obayelu, 2007). Thus, there is the danger of losing the value of public investments and its negative spill-over due to low absorptive capacity, both technical and institutional. This could increase the unit cost of public investment and deprive the country of the real value of her resources.

Absorptive capacity constraints could also undermine the rate of capital accumulation and for that matter the rate of economic growth. Whiles the causal relationship between institutional weaknesses and the capacity to transform natural resources into sustainable capital has been contested, it cannot be wished away that quality institutions are important requirements for the effective management of public finances. A look at some empirical evidence will be helpful.

Eifert et al, (2002) for instance observe that the disparity existing in the growth performance among resource-rich countries is mainly due the institutional arrangement through which resource rents are distributed, and oil would likely lead to a curse rather than a blessing if these weak institutions are not reversed.

This is supported by Mehlum et al, (2006) who drew a cross country econometric evidence that low growth performance is associated with resource abundant countries with poor institutions, while countries with high quality of institutions escape the from this effect. Therefore, countries that discover natural resources must work to build on the quality of their institutions especially public financial management institutions involved in tax collection, budget planning and auditing; as well as regulatory institutions such as licensing authority and environmental protection agencies. If there is no leap in the quality of institutions, resource wealth may not be able to move society to a “good equilibrium” where the wealth, quality institutions and economic growth converge (Vardy, 2010). Thus, institutions could become weaker as a result of resource abundance.

But there is no consensus on the relationship between growth and weak institutions. For example, Alexeev and Conrad (2009) and Brunschweiler (2008) show that a negative relationship between resource abundance and the low quality of institutions may be due to a "convergence effect". They argue that countries with poor institutions and low level of economic development between 1970 - 2000 benefited more in growth performance from resource abundance because "they were catching up, having started from lower development" This is contrary to the well known claim by Sachs and Warner (1995, 1997) that resource curse might result from weak institutions. This evidence however does not deny the importance of good governance in the effective management of natural resources.

In this wise, Ross (2010) finds econometric evidence that natural resources could discourage domestic taxation and thereby limit citizens' demand for greater transparency and accountability. He also suggests that resource wealth could increase the repressive tendencies of the state; and that the enclave nature of the natural resources sector may undermine modern changes which are relevant to democratic development (Ibid).

In spite of the lack of consensus, it remains significant for countries with natural resource abundance to build minimum quality institutions because initial conditions determine the level to which the curse will occur. This reflects the theory of "rent cycling" which emphasizes the "existence of institutional quality thresholds below which natural resource discoveries harm a country's development path" (Auty 1993).

This is due to the fact that quality institutions remove the bottlenecks that slow the rate of capital accumulation. Thus, countries with poor institutions may face problems of project feasibility, project selection, project execution, monitoring and evaluation, and the link between projects and development impacts, which are all related to public financial management. Countries that face these difficulties are said to have low institutional absorptive capacity which has implications for transforming natural capital. Table 2-1 below provides a clear comparison in the rate of capital accumulation among oil producing countries with different levels of absorptive capacity.

Table 2-1: Effects of Absorptive Capacity on Capital Accumulation – 2000

Country	**Natural Capital ($ per capita)**	**Produced Capital ($ per capita)**	**Intangible Capital ($ per capita)**
Norway	54,828	119,650	299,230
United Kingdom	7,167	55,239	346,347
Brazil	6,752	9,643	70,528
Trinidad and Tobago	30,977	14,485	12,086
Iran	14,105	3,336	6,581
Cameroon	4,733	1,749	4,271
Congo, Republic of	9,330	6,343	-12,158
Nigeria	4,040	667	-1,959

Source: World Bank (2006a) "Where is the Wealth of Nations? – Measuring Capital for the 21st Century", Washington DC.

Table 2-1 shows that countries with higher absorptive capacity are able to increase their capital stocks than those with low absorptive capacity. For instance, Norway, United Kingdom and Brazil have increased their capital stock over the years. On the contrary, the rate of capital accumulation in Iran, Cameroon, Congo and Nigeria has been very slow. In fact, Nigeria and

Congo further made negative gains in institutional capital, thus, their oil resources have weakened state institutions.

There is a significant relationship between capital accumulation from natural resources and welfare maximization and development sustainability. Development is sustainable when utility does not fall at any period along the development path (Pezzey, 1989) or where the present value of utility along the development path does not fall (Dasgupta, 2001). Thus, the fiscal rule of a country should be guided by its level of absorptive capacity. In response to the need to take absorptive capacity into consideration, the Petroleum Revenue Management Act of 2011 (Act 815) of Ghana provides that allocation of petroleum revenues to the budget should take into consideration the level of absorptive capacity. However, how absorptive capacity is incorporated into revenue allocation decision has not been addressed by the law.

2.3 Conclusion

There is no doubt that Ghana’s economy has been associated with serious fiscal problems ranging from high fiscal deficits, high trade balance, and high debt levels. Fiscal deficit by end 2011 stood at 9% of GDP and is expected to decline to 6% of GDP in 2015. But this is dependent on serious fiscal adjustments which are unlikely with the onset of petroleum revenues. Trade balance averaged 9% of GDP between 2009 and 2011 and is expected to increase to 11.9% by 2014 on account of increased oil imports from US$3,165 million in 2011 to US$3,500 million in 2013. This will further expand government expenditure and introduce another fiscal challenge. Debts levels are rising with total net Government debt expected to increase from 39.9% of GDP in 2011 to 50.5% of GDP in 2015, due to improvement in debt sustainability as a result of petroleum revenues. This could take the country’s debts to unsustainable levels and crowding out the capacity of the country to service the debts.

The fiscal outlook with the onset of petroleum revenues is therefore unlikely to show improvement as oil has the potential to fuel more spending, increase debt levels and weaken institutions responsible for fiscal management. The economy is also associated with poor public financial management systems due to fiscal indiscipline and inefficiency. This demonstrates the economy's low institutional absorptive capacity which has the tendency of undermining the impact of petroleum revenues on development.

CHAPTER THREE

OVERVIEW OF GHANA'S PETROLEUM SECTOR, FISCAL RULES AND COMPUTABLE GENERAL EQUILIBRIUM MODELS

3.1 Introduction

This section reviews the literature on the state of Ghana's oil and gas industry focusing on the early history of hydrocarbon development and recent developments leading to commercial oil production. The section also provides the theoretical and empirical foundation of fiscal rules and fiscal sustainability. It further provides the empirical basis for Computable General Equilibrium Models in the analysis of the development impacts of fiscal rules as well as measurement options for institutional quality.

3.2 Brief Overview of Ghana's Petroleum Sector

3.2.1 Hydrocarbon Development

Ghana recently found commercial quantities of oil and gas reserves. Oil exploration in reality is not new to the country. Exploration for oil and gas resources started in the 19th Century in the Western basin of the country by two companies - Societe Francaise de Petrole of France, and the African and Eastern Trade Corporation, which was a subsidiary of the then United Africa Company (UAC). These companies drilled wells in onshore Tano areas in the western regions of the country.

Ghana has always wished to find oil in commercial quantities since independence but it was not until the 1970s that commercial levels of offshore oil reserves were discovered. The discovery made in the Saltpond basin was operated by Agripetco.

In 1983, the Government set up the Ghana National Petroleum Corporation (GNPC) to promote exploration and production. The GNPC signed a number of Agreements in 1989 that led to the entry in Ghana's offshore oil industry of three companies, two American and one Dutch, who spent US$30 million drilling wells in the Tano basin.

In 1990 production begun even though it was insignificant to make the country an oil producing nation and on June 21, 1992, an offshore Tano basin well produced about 6,900 barrels of crude oil daily. The GNPC then entered into several agreements with oil exploration companies including Amoco of the United States, Petro Canada International and Diamond Shamrock among others to prospect for oil in offshore blocks between Ada, Tano Basins and the Keta Basins respectively.

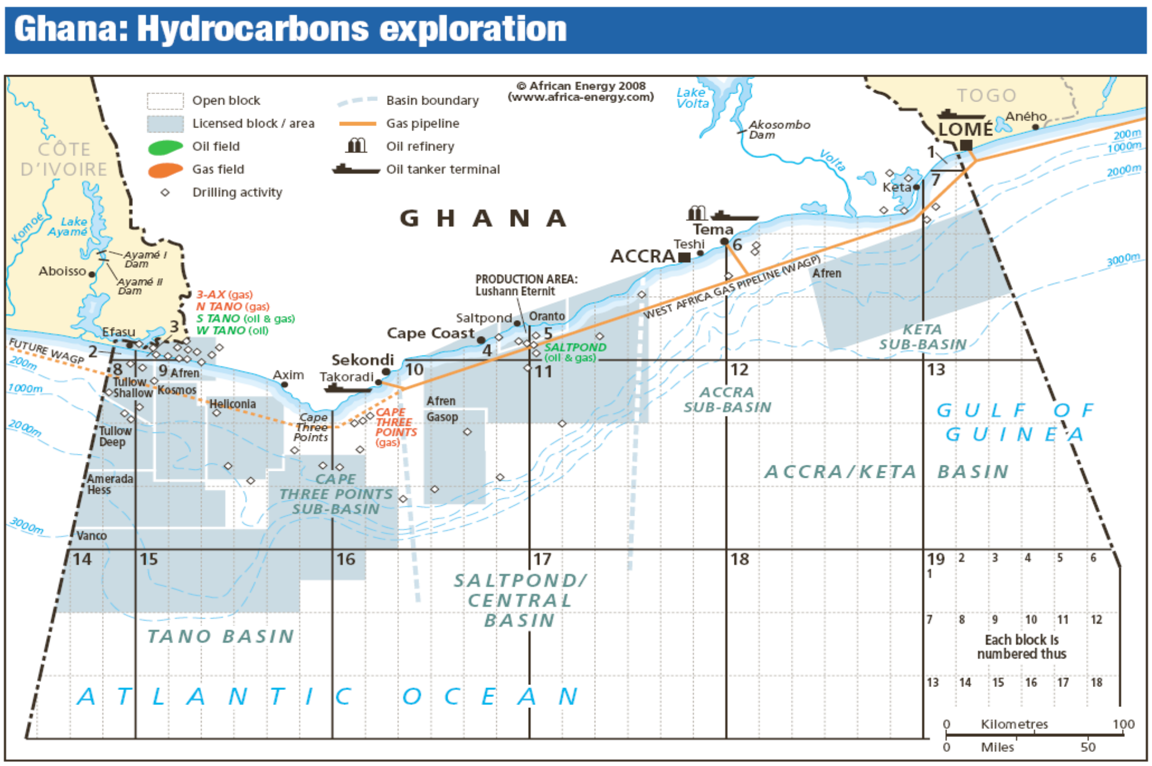
In the early 1990s, the GNPC reviewed all earlier oil and gas discoveries to determine whether a predominantly local operation might make exploitation more commercially viable. The GNPC wanted to set up a floating system for production, storage, off-loading, processing, and gas-turbine electricity generation, hoping to produce 22 MMSCF per day, from which 135 megawatts of power could be generated and fed into the national and regional grid.

The discovery of oil and gas in 2007 at the Mahogany-1 exploration well was struck by Anadarko Petroleum Corporation on the deepwater Kosmos Energy's West Cape Three Points Block, while Ireland's Tullow Oil announced the findings of its nearby Hyedua-1 well in the adjacent Deepwater Tano license. This deepwater find estimated between 800 million and 1.8 billion barrels of recoverable oil showed that there still exist huge potentials in Ghana's oil story. The new discovery perhaps opened the gate to Ghana's future prospects as a major oil and gas producing nation.

Since the discovery in the Jubilee Fields, there have been 23 other discoveries in the Deep water Tano and West Cape Three Points areas, a significant number of which have been proven to be commercially viable (Daily Graphic, "Commercial production, export of oil yields US$1.4 billion revenue for Ghana", 11th September, 2013).

There are several active other explorations going on in Ghana's waters and a reasonable activity level onshore in the keta basin. The following map shows Ghana's hydrocarbon exploration space.

Figure 3-1: Ghana's Hydrocarbons Exploration Space



Source: Africa Energy

Following the commercial discovery by Tullow Oil Ghana and Kosmos Energy Ghana, Ghana which hitherto had been named 'a graveyard' has attracted lots of attention from major oil companies. Exxon Mobil, the largest Exploration and Production Company in the world made unsuccessful bids to buy a stake in the West Cape Three Points block. The Royal Shell Oil Plc is the latest to announce its interest in securing an exploration license to operate in Ghana. Table 3-1 shows some offshore blocks that are actively being explored in the country.

Table 3-1: Oil Blocks Offshore Ghana and Ownership Structure

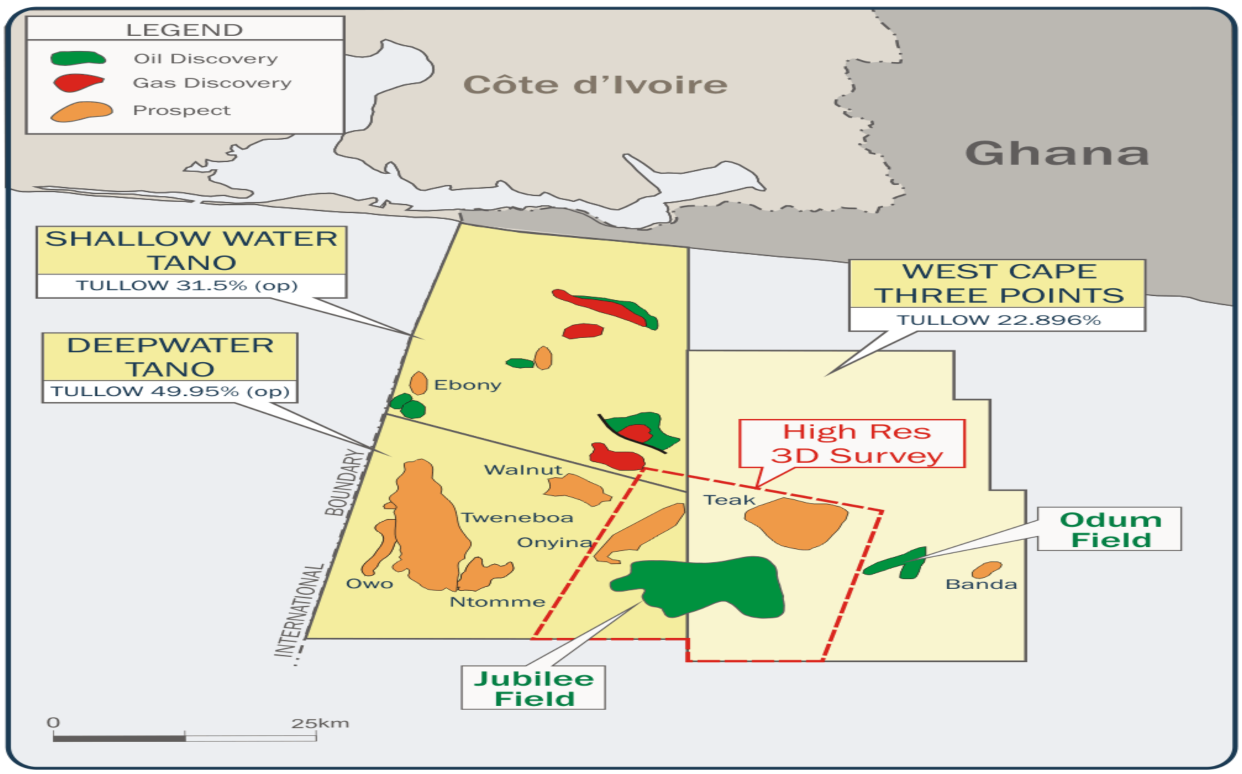
Block	**Ownership**
West Cape Three Points	Kosmos, 30.875% (operator); Anadarko, 30.875%; Tullow, 26.396%; GNPC, 10% (carried); PetroSA, 1.854%
Deep Water Tano	Tullow, 49.95% (operator); Kosmos, 18%; Anadarko, 18%; GNPC, 10% (carried); PetroSA, 4.05%
Shallow Water Tano	Tullow, 31.5% (operator); InterOil Corporation, Al Thani Emirates Petroleum Corporation, Sabre, and GNPC, 10 percent (carried)
Offshore Cape Three Points	Vitol Upstream Ghana Ltd., 85%; GNPC, 15%—some surveying done (Heliconia Energy Ghana Ltd., subsidiary of Vitol), drilling due late 2008
Cape Three Points South	Hess, block owner/operator
Cape Three Points Deepwater	Vanco Energy Company (operator) holds a 28.34% interest in the block, with Lukoil holding a 56.66% stake. GNPC, the state oil company, holds a 15% carried interest.
Saltpond oil and gas field	Small production of 750 bpd by Lushann-Eternit Energy Ltd. - Saltpond Offshore Producing Company (Lushann-Eternit, 60%; local interests, 40%); further exploration in area by Oranto Petroleum Ltd./ Stone Energy Ghana Ltd.
Keta offshore	Afren Energy Ghana, 68%; Mitsui, 20%; GNPC, 10%; Gulf Atlantic Energy, 2%

Sources: GNPC Available at: www.gnpcghana.com.

3.2.2 Ghana's First Commercial Discovery: The Jubilee Fields

In 2007, Kosmos Energy Ghana and Tullow Oil Ghana together with other partners announced the discovery of commercial quantities of oil in two blocks, West Cape Three Points and Deep Water Tano. The drilling fields on the blocks, called the Jubilee Fields, are operated under a Unitization Agreement. The Other partners on the blocks include Anadarko Petroleum Corporation and PetroSA. The Ghana National Petroleum Company has a carried interest and a paid interest. The composition of ownership in these blocks is stated in Table 3-1 above.

Figure 3-2: Detail of Jubilee Fields off the Coast of Western Ghana



Source: Tullow Oil Plc Available at: www.tullowoil.com.

According to the Environmental Impact Assessment (EIA) for the Jubilee field phase 1 development (Africa Development Bank, 2009), the Jubilee Unit Area covers part of the

Deepwater Tano and West Cape Three Points license areas. It lies in water depths of between 1100 – 1700m and covers an area of approximately $110km^2$.

Tullow Oil Ghana also drilled a successful exploration well, the Ebony 1 in the Shallow Water Tano license area. There are other active on-going drilling, development, appraisal, and at least three additional high-impact exploration wells which include Tweneboa, Teak, and Onyina. Other exploration wells have been drilled in the Keta block and the South Deepwater Tano block. As already stated, by December, 2012, the number of discoveries stood at 23, giving Ghana one of the highest exploration success rates in the world.

The development of the Jubilee fields was preceded by the approval of a Field Development Plan by the Government of Ghana in line with the Petroleum (Exploration and Production) Law (PNDC Law 84 of 1984) and the Model Agreement Framework. The development of the fields went through a fast-track approach in three years with production commencing in December 2010. The development phase covered field development, sub-sea infrastructure, and the manufacturing of the Floating Production and Offloading (FPSO) Vessel in Singapore.

3.2.3 Ghana's Petroleum Revenue Management Policy

Ghana's petroleum policy is an integral part of the National Energy Policy (Government of Ghana, 2010a). The main goal of the policy is to "sustain and optimize the exploitation and utilization of Ghana's oil and gas endowment for the overall benefit and welfare of all Ghanaians, present and future".

Several challenges confront the upstream subsector including for example how to increase and sustain investor interest in exploration activities, maximization of local content, efficient management of petroleum revenues, environmental sustainability and the security of petroleum installations. In order to address these challenges, the Government further formulated the National Energy Strategy (Government of Ghana, 2010b), which prescribes measures for addressing the challenges.

The strategy includes the enactment of appropriate laws to give effect to the policy. Some of the laws in Ghana that are relevant to the petroleum sector are:

a. The Ghana National Petroleum Corporation Law 1983 (PNDC L 64);

b. Petroleum (Exploration and Production) Law 1984 (PNDC L 84);

c. Petroleum Income Tax law 1987 (PNDCL 188);

d. Internal Revenue Act 2000 (Act 592);

e. Maritime Security Act 2004 (Act 675);

f. Petroleum Revenue management Act 2011 (Act 815);

g. Petroleum Commission Act 2011 (Act 821)

The Petroleum Revenue Management Act 2011 (Act 815) defines the framework for managing oil and gas revenues accrued to the state. The Act specifies clear rules for the inflow and outflow of oil and gas revenues, including expenditure allocation options. The main features of the Act are; the fiscal framework, collateralization of petroleum revenues and a strong transparency framework.

Section 3(1-2) of the Act establishes a Petroleum Holding Fund to which all petroleum revenues must be deposited. Apart from certain exceptional circumstances, including for example, refunding tax overpayment, paying management fees, paying royalties for onshore petroleum operations, or repairing communities adversely affected by petroleum operations, petroleum revenues deposited in the Petroleum Holding Fund must be transferred to the consolidated account for budget spending, the Stabilization Fund and the Heritage Fund.

The Finance Minister is required by the Act to determine the annual “Benchmark Revenue” for the next financial year latest by October 1st. The Minister is then required to allocate 70% of “Benchmark Revenue” to the budget, 21% to the Stabilization Fund and 9% to the Heritage Fund. The purpose of the allocation to the budget is to meet development needs of the country, which is also called the “Annual Budget Funding Amount”.

The level of the Annual Budget Funding Amount shall be guided by the country’s medium term national development plan and the level of absorptive capacity. The Minister is therefore required to prioritize not more than four areas for the spending of petroleum revenues, which shall be reviewed every three years. The Annual Budget Funding Amount shall be collateralized for a period not exceeding 10 years. The Stabilization Fund is to cushion the budget against crude oil price volatility, while the Heritage Fund is an endowment Fund to meet inter-generational equity. This is also called Future Generations Fund.

Withdrawals from the Ghana Stabilization Fund may be done in two ways depending on which is lesser. On one hand, when petroleum receipts in any quarter falls below 25% of the Annual Budget Funding Amount, 75% of the estimated shortfall shall be withdrawn from the Stabilization Fund.

On the other hand, 25% of the balance standing in the Stabilization Fund can be withdrawn. The Heritage Fund cannot be spent until the petroleum resources are depleted. However, Section 10(4) of the Act allows Parliament to review the restrictions on the Heritage Fund by simple majority to authorize spending of a portion of the interest accrued to the Fund after 10 years. When petroleum resources are depleted, the Stabilization Fund and the Heritage Fund shall be merged into the Ghana Petroleum Wealth Fund. At this point, the Annual Budget

Funding Amount shall not exceed the total amount of dividends from the national oil company and returns on the Ghana Petroleum Wealth Fund.

Further, the Minister of Finance is required by Section 23 of the Act to determine the maximum limit of the Stabilization Fund and to ensure that any excess revenues over the maximum limit are transferred to the 'Contingency Fund or used for debt repayment'.

The fiscal framework for managing Ghana's revenues underscores the relevance of prudent management of resources, the need to accelerate economic development and to achieve inter-generational equity. While the provisions of the Act are generally positive and reflect best international practices, there are concerns on many aspects of the Act, which requires some discipline on the part of the managers of the economy.

The provision for collateralization of future petroleum revenues may undermine fiscal sustainability. The danger is that petroleum revenues are not permanent even as they are volatile and therefore, while revenues will eventually decline during the depletion stage of the country's oil fields, unpaid accumulated debts become a burden at the time petroleum revenues are insufficient to service these debts, particularly when the loans are not spent efficiently. Thus, future development is inconveniently sacrificed with serious implications for future generations.

Also, the provision to spend a portion of the interest on the Heritage Fund by simple parliamentary majority is likely to negatively affect the growth of the Fund which then defeats its endowment objective. Fact is that the Government of Ghana has historically not controlled spending as demonstrated in the persistent fiscal deficits recorded in the national budget over the years. Such appetite for spending will likely entice the Government to use its majority in parliament to deplete the Heritage Fund.

Another important issue relates to the provision to transfer excess revenues over the maximum limit of the Stabilization Fund to the Contingency Fund. The Government's Contingency Fund is a discretionary Fund which is spent by the Minister without recourse to the requirements of the Petroleum Revenue Management Act. That is, the Minister could spend it outside the priority areas specified in the Act. Also, there are several portions of the Act that are too loose and provide avenues for abuse of discretion. Thus, Ghana's fiscal rule requires strong institutional frameworks to check potential abuse and ensure that petroleum revenues are managed in line with the country's development objectives.

3.3 Literature on Fiscal Rules and Fiscal Sustainability

3.3.1 Definition of Fiscal Rules

There is significant academic literature on why unconstrained discretion over fiscal policy can cause problems for public finances and create macroeconomic instability. The problem associated with resource-rich countries is the temptation to meet the increasing pressure for spending against volatile revenues. There is also the fear to raise taxes to finance public expenditure in what has become known as fiscal illusion and a deficit bias which also have implications for inflation (Obinyeluaku et al, 2008).

Fiscal rules are statutory or constitutional restrictions that set specific limits on fiscal indicators such as budgetary balance, debt, government spending, or taxation (Kennedy and Robbins, 2001). Primarily, fiscal rules seek to disengage fiscal policy from government influence much like the separation of monetary policy embodied in inflation-targeting frameworks. They also impose greater accountability on government finances, drive expectations and enhance transparency of the overall budgetary framework.

Again as noted by Brunila (2002), such rules help tackle a country's predisposition to budget deficits by pre-empting possible spending over-runs and thereby help to address the political and institutional tendencies to raise expenditures during economic booms. However, Kopits and Symansky (1998) introduced time frame for fiscal rules by defining fiscal rules as "…permanent constraint on fiscal policy, typically defined in terms of an indicator of overall fiscal performance". This raises fundamental issues.

Rules must have long-term horizons and therefore in natural resource-rich countries for example, which are faced with resource exhaustibility problem, fiscal rules could be used to solve macroeconomic difficulties associated with resource exhaustion. Also, rules are indicators for measuring fiscal performance because they are expressed in numerical terms and are usually without ambiguity. They define the framework for resource inflows and outflows and indicate the fiscal capacity of the state under alternative fiscal policy choices.

Over the past decade and a half, fiscal rules have gained attention in a number of countries. New Zealand played a pioneering role in formulating a Fiscal Responsibility Law (FRL) to maintain and strengthen fiscal discipline. Although subsequent designs of fiscal rules vary across countries, they all subscribe to basic characteristics considered important for effective implementation (Kopits and Symansky, 1998). As at 2010, there were about 80 countries with fiscal rules compared to about 10 by 1990. The growth in the preference for fiscal rules may be due to increased macroeconomic and financial instability experienced by many countries. Following the global financial crisis in 2007/2008, many countries adopted new fiscal rules to provide guidance for fiscal policy.

Most models of resource revenue management are aimed at solving inter-temporal portfolio problem to measure the optimal level of government consumption and saving. They are also aimed at solving the problem caused by the instability of resource prices. Resource-rich countries are therefore confronted with three fiscal policy dilemmas. First, there is pressure to spend resource revenues on current development priorities to accelerate growth and reduce poverty. Second, natural resources are exhaustible and impose intergenerational equity concerns and future fiscal sustainability when resources are depleted. Third, the prices of natural resource are very volatile and could destabilize revenues and development outcomes. Resource-rich countries are therefore always faced with the difficulty of determining the balance between spending and saving, as well as choosing the optimal mix of spending portfolio which has proved very challenging.

The theoretical framework formulated by Milton Friedman (1957) which has both stabilization and intergenerational factors is the Permanent Income Hypothesis (PIH). This theory posits that governments should be forward-looking and must be able to smooth consumption over time which should not deviate from the annuity present value of expected resource rents. Thus the most viable rule that fulfils both objectives of fiscal sustainability and intergenerational equity is the permanent income rule.

Permanent income is defined as the rate of return on a country’s resource wealth, which in turn is equal to the present discounted value of future resource revenues. The rule ensures intergenerational equity because the annuity value of expenditures would be constant across generations and would continue after the resources are completely exhausted. It also avoids boom-bust cycles because expenditures out of resource revenues would be stable. This is because changes in current prices of natural resources have insignificant effect on computations about long-term value of reserves as well as the revenue stream for current spending. Where prices are stable, the rule can also ensure sustainability by targeting non-oil deficits to be exactly equal to the return on discounted resource wealth.

Consumption smoothing and the long-run optimal level of consumption which theory predicts depend on some factors including intergenerational equity considerations, the expected reserves, the real interest rate, the growth rate of non-resource output, the rate of population growth, etc. Again the PIH means that a windfall is perceived as an increment to wealth, and consumption from the wealth is smoothed through time. This hypothesis is similar to the tax smoothing literature (Barro, 1979) or the optimal use of the current account (Sachs, 1981).

The Permanent Income (PI) rule entails use of the Permanent Fund for Future Generations to secure intergenerational equity and guarantee a permanent flow of resources that will foster economic development even after oil resources have been exhausted.

While the PI rule is advantageous in some respects including maintaining fiscal sustainability, it also creates social tensions because public spending would be low at the time resource revenues are being accumulated for future spending. Therefore, this rule does not take into consideration that resource revenues might be used for domestic development needs capable of enhancing short-term and long-term welfare beyond the rate of return on financial assets sterilized abroad (Heuty and Aristi, 2010).

In addition, the rule may not be ideal for developing countries due to capital shortages and higher social investment returns of public investment compared to returns on financial assets and this justifies the need to spend oil wealth upfront on public investments to enhance productivity and consumption (Takizawa et al, 2004; Van der Ploeg and Venables, 2009). The use of Net Present Value to calculate the value of reserves relies on future oil prices, new discoveries and available technology (Heuty and Aristi, 2010) and which may change the fiscal benchmark of the PI rule.

In theory, there are other identifiable fiscal rules that are being applied in resource-rich countries. The first is the balanced-budget rule or what is commonly called 'hand-to-mouth' or 'going-on-a-binge' rule, which implies spending all resource revenues as they accrue to the government. It is also called the "big-push". It is aimed at maintaining a balance in fiscal position. This rule is good for countries with serious current developmental challenges.

Takizawa et al, (2004) argue that the front-loaded spending of oil wealth, implicit in this rule, is justified when the country is in dire need of public investments and infrastructure that are essential for long-term growth and private investments. However, the rule favours current spending at the expense of future generations and also lends government budgets to extreme volatility in response to price changes.

The second rule is the 'bird-in-hand' rule, which requires that only the interest income made on accumulated net financial assets from resource revenues be spent. It favours intergenerational equity. It is also good at sterilizing resource revenues and minimizing Dutch Disease effects. However, while this rule avoids subjecting the government budget to spending volatility, it does not provide to the economy the needed capital spending for growth. Also, it would be more appropriate for a country at a much higher level of development.

The third rule is the medium-term price rule, under which resource revenues valued at a medium-term price are spent and the balance is saved. This is the rule that is largely followed by Chile in its Copper Stabilization Fund (Fasano, 2000; and Davis et al, 2002).

There is also the 'structural balance' rule which allows for temporary deviations in the overall nominal deficit from its medium-term target in line with cyclical developments. This can be adjusted into an ‘augmented growth-based’ rule where the deficit is allowed to be higher when GDP growth in the current year is below its trend level, and requires a gradual adjustment of the balance to the target level when the initial deficit is above target; and an ‘augmented structural balance’ rule which incorporates, in addition to ‘structural balance rule, an automatic correction mechanism to past deviations from the target.

The basic structural balance rule works effectively by allowing automatic stabilizers to operate during the periods in which there is a nonzero gap in output. The rule is however not very successful at reducing public debt in the aftermath of the shock. The augmented structural balance and the augmented growth-based balance rules both provide room for countercyclical fiscal responses, but have also got mechanisms which cover some degree of fiscal policy correction in line with debt sustainability. All these rules except the PI rule, however, do not guarantee fiscal sustainability or optimal intergenerational consumption of resource wealth at the same time.

3.3.2 Measurement of Fiscal Sustainability

Fiscal sustainability is measured as a percentage of GDP or better still in the case of an oil producing country, as a percentage of non-oil GDP. Most fiscal rules target fiscal deficits or public debt levels, and therefore define certain constraints on revenue or expenditure levels.

Fiscal sustainability analysis is an important segment of the overall fiscal management framework in developing countries. The measurement of fiscal sustainability takes into consideration the exhaustibility of petroleum reserves, the financial position of the government, and inter-temporal welfare choices expressed in Net Present Value of future petroleum revenues.

Villafuerte and Lopez-Murphy (2009) outlined different set of fiscal indicators, including the non-oil primary balance that is a key indicator in those countries.

The ‘overall fiscal balance’ is widely used and has proved very useful for assessing the public net financing requirement and fiscal vulnerability. Its shortcoming is its inability to measure the effect of fiscal policy on domestic demand or the government’s adjustment effort especially for countries with petroleum revenues whose fiscal expansion through increased spending may be covered under the balance.

The ‘non-oil balance’, which excludes net oil revenue is a better indicator of the impact of fiscal policy on domestic demand since oil revenue mainly originates from abroad particularly for countries where petroleum revenues constitute more than 50% of overall revenues. These countries are regarded as petroleum dependent countries and survive on revenues from exports of oil and gas which do not reduce the resources of the domestic private sector. This fiscal measure is a more reasonable measure of the impact of oil revenue injection in the economy, and the level of fiscal effort.

The ‘non-oil primary balance(NOPB)’ is a further improvement over non-oil fiscal balance by excluding from the non-oil fiscal balance both interest receipts associated with accrued financial savings in oil funds and payments. Interest receipts and payments are not under the control of the government. This fiscal measure is the most appropriate way to assess fiscal sustainability through comparisons against long-term fiscal benchmarks based on inter-temporal government wealth considerations.

The ‘cyclically-adjusted non-oil primary balance’, is synonymous to automatic stabilizers because it excludes the effect of the economic cycle on non-oil revenue and expenditures. It is a very useful fiscal measure because it allows the identification of the portion of the fiscal position that would be the direct result of discretionary fiscal policy decisions.

Fiscal sustainability measures are based on either an annuity model or perpetuity model. The annuity model is usually applied to countries with limited oil reserves whose consumption path is in a generation. The perpetuity model applies to countries with frequent discoveries and reserve accumulation. The annuity model has been extensively applied in Barnett and Ossowski (2003) and Carcillo et al, (2007), which are aimed at ensuring a smooth non-oil primary spending consistent with inter-temporal solvency and intergenerational equity. The model takes into account the present value of future net petroleum revenues, non-oil GDP growth and interest rate projections, non-oil revenue and grants outlook, the initial level of serviceable public debt, and the speed of adjustment.

There is considerable level of empirical work on fiscal policy in resource-rich countries. These empirical works have however focused more on broad fiscal policies but issues of fiscal rules and fiscal sustainability and the determination of fiscal benchmarks and their effects on the economy remain a challenge in the literature. Most of the existing literature on fiscal sustainability also employed a framework focused on government wealth inclusive of oil in the ground (Tersmen, 1991; Liuksila, Garcia and Bassett, 1994; Chalk, 1998; Barnett and Osswoski, 2002), and this reflects the permanent wealth model, which is the PI rule of fiscal management.

The International Monetary Fund (2010) observes that several countries have implemented fiscal rules based on some fiscal indicators. For example, in India, a gradual fiscal consolidation is envisaged by reducing the central government fiscal deficit to 3% of GDP by 2013/14. The planned reduction would be mainly revenue-driven, from higher growth; and from measures to simplify the tax code, raise voluntary compliance, and reduce exemptions.

Also, Indonesia also has a gradual fiscal consolidation envisaged with an overall deficit target of 1.2% of GDP in 2014. The consolidation is revenue-based with a projected increase in the revenue-to-GDP ratio of 1.6 percentage points (2009–14). This is underpinned by reforms to modernize tax administration and enhance tax collection as well as policies aiming to increase oil and gas production. The expenditure-to-GDP ratio is projected to increase gradually to support economic development and poverty reduction (Ibid, 2010).

In a study on Sudan, Ali Abass et al, (2010) measured fiscal sustainability and the speed of fiscal adjustment based on the annuity model. The study used the standard framework of an inter-temporal optimization problem of a finite, natural resource economy bearing some initial level of public debt to determine fiscal sustainability based on the Permanently Sustainable Non-oil Primary Balance (PSNOPB). The optimization problem for the government according to the study comprises an inter-temporal choice of the size of the non-oil primary fiscal balance; and an inter-temporal choice of expenditure and (lump-sum) taxes consistent with that balance, provided by the exogenously given path of oil revenue and interest rate.

They further observe that one of the major challenges of fiscal sustainability is uncertainty faced by oil producing countries regarding inter-temporal welfare choices. These uncertainties are caused by levels of oil reserves, oil recovery rate, crude oil prices and cost of production. To check these uncertainties, fiscal sustainability analysis has relied on the Permanent Income Hypothesis, which provides a consumption smoothing path over time.

Villafuerte and Lopez-Murphy (2009) measured fiscal sustainability by comparing fiscal positions of different oil producing countries based on cyclically adjusted non-oil primary balance against ‘sustainable fiscal benchmarks’ as an annuity rather than perpetuity and thereby took care of the exhaustibility of the resource. In their paper, the standardized approach of fiscal sustainability assessment across countries was used. The findings are that due to exhaustibility particularly for countries with limited oil reserves, a sharp fiscal adjustment is required at the end of the consumption horizon. They also find that most oil producing countries deteriorated in their fiscal sustainability positions due to huge expansions in NOPB in spite of the higher crude prices prevailing during the period of the study.

The model applied in this study takes into account the present value of future net petroleum revenues, non-oil GDP growth and interest rate projections, non-oil revenue and grants outlook, the initial level of serviceable public debt, and the speed of adjustment. The methodology is based on the twin assumptions of consumption smoothing and inter-temporal solvency to measure sustainable NOPB trajectory under various public debt reliefs and speed of adjustment scenarios and compared this trajectory with the end-2008 NOPB-to-NOGDP ratio which yields a measure of the requisite medium and long-term adjustment.

Based on the permanently sustainable NOPB approach and a general equilibrium neoclassical growth framework, the study finds that the required fiscal adjustment over the medium term is 4–10 percent of NOGDP, with the lower bound of 4% obtained under fairly realistic assumptions of an annual adjustment rate of 25% and a serviceable debt stock equivalent to 25% of the total public debts.

In a study by Baunsgaard (2003), he designed a fiscal rule nested within the long-run sustainable use of petroleum revenue in Nigeria. In this study, two specific fiscal rules are examined – the permanent price rule which targets a balanced budget at a reference crude oil price and a non-oil primary deficit rule which targets a 20% deficit relative to non-oil GDP. The study measured the country’s stock of wealth in real terms and permanent real wealth in per capita terms. These could qualify as PI rule and Population Adjusted rule provided they are equated to the non-oil primary deficit. However, the two specific rules examined in the study had different targets.

The results of the study show that non-oil primary deficit of 15-25% of non-oil GDP would be required to maintain the real wealth over time under various price and production assumptions. The permanent price rule is however more effective in stabilizing the non-oil primary deficit. The findings also show that both rules are not prone to crude price volatility. But volatility in revenue will impact on overall fiscal balance as a change in fiscal composition while non-price volatility will impact on the rules differently. An important finding in this study is that the non-oil primary deficit rule will insulate the budget from volatility caused by changes in production, production costs, the fiscal regime and the impact on petroleum revenues from exchange rate movement.

Obinyeluaku et al, (2008) follow the work of Baunsgaard (2003) and Basci et al, (2004), and conducted a study which looked at different fiscal rules in Nigeria. They refer to revenues under uncertainty as stochastic revenues. The paper examines the appropriate fiscal policy rules that can produce better performance in reducing debt accumulation and promote the necessary medium-term budget deficit stability in Nigeria. In this study, two alternative policy rules are considered, the Fixed Primary Surplus Rule and the Variable Primary Surplus Rule.

The study draws a comparison between the fixed primary surplus rules to an alternative, the variable primary surplus rule, in which the primary budget surplus is defined as an increasing function of the debt-to-GDP ratio. It decomposes the primary surpluses into gross budgetary revenue and non-interest budgetary expenditure to account for both volatility in revenues and control for the government expenditure since government revenues in Nigeria is largely exogenously determined, an important departure from the literature. The simulation in the study follows Monte Carlo technique.

The study concludes that government's ability to make credible commitments to a fiscal rule depends on the flexibility of fiscal expenditure. That is both the Variable Surplus rule and Fixed Surplus rule perform well under different conditions. The Variable Surplus rule for instance is found to perform better than the simple Fixed Surplus rule, by reducing debt accumulation and the necessary medium-term Primary Surplus whiles the Fixed Surplus rule works better when the real interest rate is relatively high.

Manasse (2006) assesses the role of shocks, fiscal rules and institutions as possible sources of pro-cyclicality in fiscal policy. Using parametric and non-parametric techniques on a sample of 49 emerging and industrial countries for the period 1974-2004, he concludes that policy makers' reactions to the business cycle are different depending on the state of development. He also suggests that fiscal rules and fiscal responsibility laws tend to reduce the deficit bias on the average and that strong institutions are associated with a lower deficit bias, but their effect on pro-cyclicality is different in good and bad times.

Thornton (2007) analyzed the cyclicality of government revenue, spending and the fiscal balance in South Africa during 1972-2001. He suggests that while government revenues were largely anti-cyclical, government spending appears to be largely countercyclical in line with the recommendation of neoclassical model. In addition, countercyclical government spending policy appears to have translated into a countercyclical policy stance in general, as measured by the overall fiscal balance.

Resource-rich countries in Africa have not been successful with fiscal rules ranging from the Permanent Income rule, the bird-in-hand rule, the hand-to-mouth rule; and price based and expenditure growth rules. Most of these countries have suffered from fiscal indiscipline.

Also, countries that implemented countercyclical policies have not had any impact on the degree of pro-cyclicality (Arezki et al, 2011). Those that introduced permanent income elements in their fiscal policies such as Chad and Equatorial Guinea sometimes abandoned them when pressure for public investment increased. There are also other unsuccessful countries like Nigeria and Sudan due to weak institutional frameworks for the implementation of fiscal rules, and where rules have been circumvented. For some countries like Gabon and Congo Republic, it has also been observe that fiscal rules forced adjustments in capital spending during bust period which raised concerns about growth prospects (Arezki and Ismail, 2010).

There are also other countries that faced design difficulties by failing to account for the revenue horizon from their natural resources. Short-term horizons where resource revenues are temporary, requires rules that emphasize fiscal sustainability; whilst long-term horizons need to emphasize fiscal stability. For example, with its long-term petroleum revenue horizon, Nigeria's macroeconomic stability has been a major challenge. Not even the passing of a Fiscal Responsibility Law helped in improving macroeconomic performance until quite recently in 2011 and 2012.

With the development of fiscal rules for measuring Ghana's petroleum revenue allocation, the rule must be guided by a number of factors. With a short-term oil revenue horizon, the fiscal rule should address the fiscal sustainability challenge. However, this does not necessarily guarantee the extent to which fiscal sustainability could affect development outcomes. It is simply a precautionary measure. There should also be strong institutional frameworks to implement fiscal rules.

3.4 Computable General Equilibrium Model (CGEs)

3.4.1 Brief History of CGEs

Analysis of aggregate economic phenomena from a general equilibrium perspective started with Walras in his publication of Elements in the late nineteenth century (Walras, 1874). But it was Keynes' General Theory in which general equilibrium analysis was first developed to explain macroeconomic fluctuations in general and the Great Depression in particular (Keynes, 1936).

Computable General Equilibrium models are fairly recent dating back to early 1960s. CGE models have gained much attention as a standard model for analyzing traditional economic policies such as, fiscal policy and optimal taxation (Slemrod, 1983), trade policy (Devarajan and Rodrik, 1989), income distribution (Bandara, 1991), structural adjustment, trade, etc. (Gunning and Keyser, 1993), sector development (Robinson et al, 1993, for agriculture), and environmental issues (Kokoski and Smith, 1987), social, environmental, and poverty (Conrad, 1999; Munasinghe et al, 2005).

CGE models are described as the modern version of Walras model of the competitive economy. It is important to note that the first CGE model was developed by Leif Johansen (1960) in his seminal work to analyze growth in the Norwegian economy. Johansen developed a multi sectoral model (20 sectors) and an input-output model in line with Walrasian general equilibrium theory based on fixed coefficients of intermediate and value added production function. Johansen's model involved linear approximation of the model by taking the logarithmic derivatives of the non-linear CGE model, and then applied simple matrix inversion.

Herbert Scarf (1967) was however credited for the introduction of an algorithm for the solution of the general equilibrium problem of Walrasian system. This built the foundation for the development of applied general equilibrium models which was used to compute general equilibrium prices. Thus, Scarf was the first to draw direct link between theoretical work and the empirical CGE modeling. He also made an improvement on Johansen's model by designing a fixed point algorithm for deriving solutions to numerically specified models, without a prior linear approximation as did Johansen (Dixon and Parmenter, 1996).

Shoven and Whalley (1972), a student of Scarf's, made a significant contribution to CGE models by introducing a fully disaggregated CGE model to study the effects of differential taxation on incomes from capital. This was based on data from the United States economy.

Jorgenson (1974) also extended CGE model by introducing a calibration technique to estimate supply and demand; and applied the model to production and national accounting. However, it was the work of Dervis De Melo and Robinson (1982) which made a significant advance in the formulation of CGE models and applying them to measure the impact of policy decisions.

Several pioneering efforts followed these earlier developments. For instance, the first to introduce dynamic features into the modeling of economic behavior of consumers were Ballard (1983); and Auerbach and Kotlikoff (1983). Similarly, the first attempt at implementing dynamic features to model economic bahaviour of the producer was Bovenberg (1985) and summers (1985).

The introduction of the General Algebraic Modeling System (GAMS) was a significant development in the CGE modeling literature (See Brooke et al (1988)), as it contributed to a quicker solution of CGE analyses by its ability to deal with large number of parameters.

CGE models can be categorized by different specifications. First, they are classified by literature survey and by subject category such as Shoven and Whalley (1984), De Melo (1988), and Pereira and Shoven (1988), on trade policies; Bergman (1988) and Bhattacharyya (1996) on energy and environmental policies; Bandara (1991) on development policies in Least Developed Countries; Robinson (1991) on “micro-macro” CGE models that incorporate assets, products and factor markets, and recently Kraybill (1993) on comparison between the regional CGE approach to input-output analysis; among others.

Second, they are categorized by geographic coverage. These include CGE models that have been limited to country levels and those extended to regional policy studies particularly for studies of the German Regions (Conrad and Schroder, 1993; and Hirte, 1998); and the Italian Regions (D. Antonio et al, 1988).

Third, Naqvi (1998) categorized CGE models by modeling approach. These include Johansen’s non-linear, multi-sectoral growth model which focuses on sectoral allocation of capital and labour and distribution of sectoral output, followed by Harberger-Scarf-Shoven-Whalley linearized model focusing on welfare economics; by Jorgenson econometric estimation approach; and by Ginsburgh and Walbroek (1981) linear programming approach.

General equilibrium models are also categorized according to one period against inter-temporal analysis. These are also known as static CGE models and Dynamic CGE models.

3.4.2 Type of CGEs

a. Static CGE

Static models have two periods of adjustments – short run and long run. The key difference in most models is that capital is fixed (exogenous) in the short run but free to adjust in the long run. Most conventional CGEs used in early modeling were static CGEs such as Shoven and Whalley model (1972) and Dervis, De Melo and Robinson model (1982). However, there are also recent models such as Robinson, Yunez-Naude, Hinojosa-Ojeda, Lewis and Devarajan (1999).

Static models measure the effect of policy at a certain future by calibrating the model based on a dataset usually a Social Accounting Matrix, in which a steady-state growth has been established. Thus, the model creates savings and investments as well as demand for capital goods. In this case, investments represent a demand category whilst capital goods are uninstalled in the period.

The first generation of CGEs was static in nature. But dynamic models emerged later. Very recently, CGEs have moved from traditional static to very dynamic models in line with inter-temporal optimization (Harrison et al, 2000; Dixon and Rimmer 2002; Bell, Devarajan, and Gersbach, 2003).

b. Dynamic CGE

These are CGEs that consider multi-period and focuses on inter-temporal effects of policy decisions. The inter-temporal effects of policies are often interrupted by Government interventions over time, which has the tendency of taking the economy into disequilibrium. Thus, there must be a mechanism to restore the equilibrium through the generation of effects in either a recursive or fully dynamic process. That is, dynamic CGEs can further be classified as "Recursive Dynamic' or "fully dynamic".

The first treatment of dynamic general equilibrium analysis can be traced back to La Volpe's (1936) and Hicks (1939), in which they explained that current behaviour is influenced by backward-and forward-looking expectations. These were later followed by Ballard (1983) and Auerbach and Kotlikoff (1983), but Ballard, Fullerton, Shoven and Whalley (1985) were the first to introduce dynamic features in CGE models.

Other pioneers in dynamic CGE models are Bovenberg (1985) and Summers (1985) who applied dynamic features to the behavior of producers. The introduction of dynamic features into CGE models was because many of the questions the models were expected to answer were dynamic in nature.

i. Recursive Dynamic CGE Models

The recursive process involves a sequence of static equilibria which are connected through capital accumulation or investment distribution. Other variables such as labour and population are updated as exogenous variables.

Recursive Dynamic CGE models are classified into two by Dixon and Parmenter (1996), depending on the expectations of economic agent's behaviour. One of these recursive processes is based on static expectations and the other on adaptive expectations. In the former case of expectations, savings rates are treated as exogenous whilst investment is expressed in total savings over the period. In this case future investments depend on the expected rate of returns. In the latter case, the adaptive expectations assumption, the behaviour of economic agents depends on the past to determine the future behavior of the economy. Thus, returns on future investments depend on the previous year's rate of return and cost of capital.

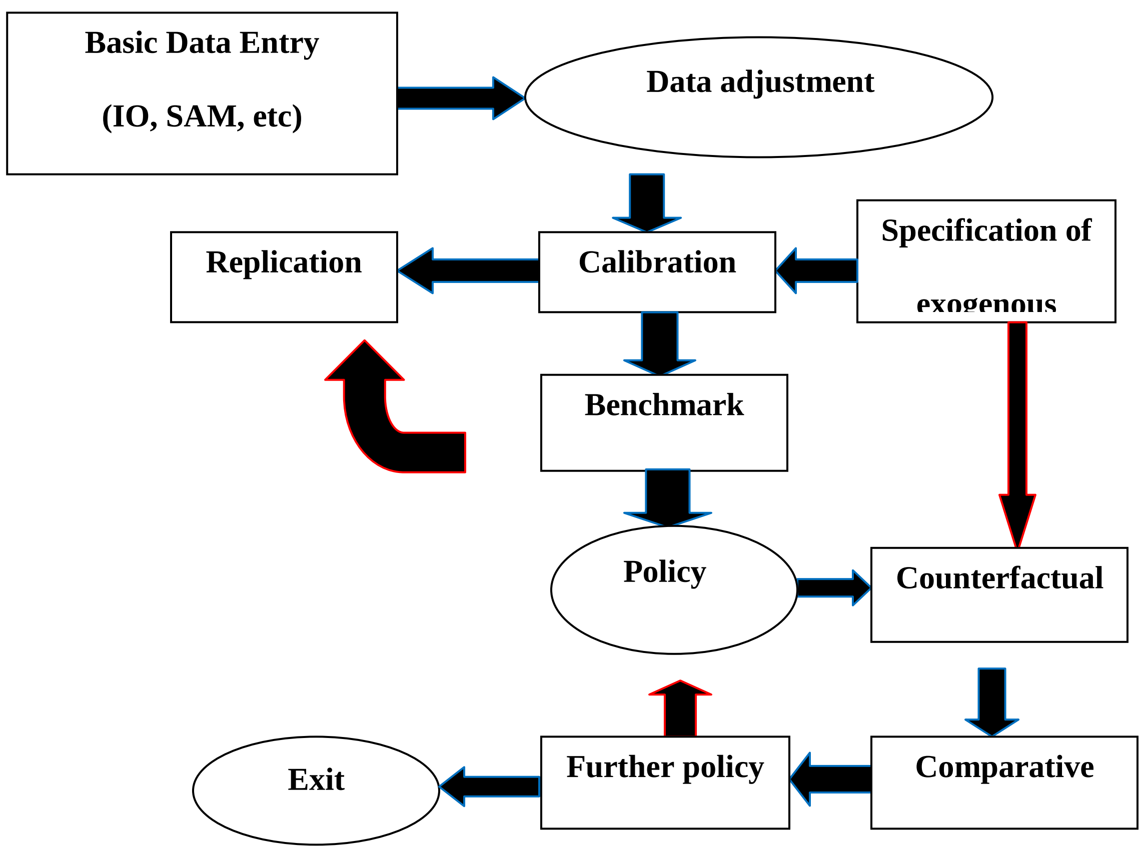
ii. The fully Dynamic CGE Models

The models associate the behaviour of economic agents to both intra and inter-temporal optimization and thereby have life-cycle behaviour. Both consumers and producers face constraints that affect their behaviour. For instance, the consumer is faced with maximizing a time-invariant inter-temporal utility function; whilst the producer is faced with maximizing the market value of the firm.

The capital adjustment costs in the dynamic process influences the behaviour of production and investments through Tobin's Q theory. The adjustment costs cover the installation cost of capital and the cost of the unlimited capital mobility across industries. Government behaviour as well as financial markets and international trade can also be modeled with dynamic features.

The following figure 3-3 is a schematic presentation of the modeling process of CGE models.

Figure 3-3: A Basic CGE Modeling Process



Adopted from Shoven & Whalley (1998), Applying General Equilibrium, p. 104.

3.4.3 CGE Models for Resource producing countries

Empirical studies in the public expenditure literature have focused on the impact of government consumption and public investment on economic growth. Indeed, majority of studies find that there exist strong negative correlations between the size of government consumption on goods, services and wages; and economic growth for various groups of countries (Barro, 1991).

There is however no consensus on the impact of government capital investment with some arguing that such investments have little impact on growth compared with private investment (see Barro, 1991; Calderon, 2004; and Khan and Kumar, 1997). However, in Aschauer (2000), if the growth equation is controlled for the effectiveness of public capital expenditure, the impact of such investments may be stronger. This is what the study seeks to prove, accounting for the impact of institutional quality or efficiency in public spending.

There are many neoclassical growth models that allow for the impact of government operations on resource allocation and growth. Some of these models seek to derive the optimal government expenditure or taxation paths (see Barro and Sala-i-Martin, 2004), whilst others focus on the impact of alternative fiscal rules (see Judd, 1985; Barro, 1989; and Baxter and King, 1993). Both types of models were applied to the analysis of public expenditure in the context of oil-producing countries (for example, Engel and Valdés, 2000; and Takizawa, Gardner, and Ueda, 2004).

The first set of CGE applications to developing countries focused on problems of optimal taxation and trade policies; but two decades later, applications emerged for specific countries including Korea (Adelman and Robinson, 1978), and Brazil (Taylor et.al., 1980).

It must be noted however that unlike the theory of optimal taxation which was developed to analyze fiscal policy impact; there exists no theory of optimal expenditure policy except the ideas of expenditure policy which are based on determining government expenditure to correct market distortions arising from externalities and market failure (Stefano, Anand, and Erwin, 2005; Steven, 2001).

In the 1980s, CGE applications in developing countries centered on the issues of poverty, income distribution and development strategies, stretching to structural adjustment and stabilization policies to solve the debt crisis and trade problems that confronted many developing countries and who were in search for strategies.

In the 1990s, CGE applications in addition to addressing poverty and income distribution issues, extended to environmental and energy problems (Devarajan, 1997; Adkins and Garbaccio, 1999). Also emerging during this period were applications of CGE models to natural resource allocation or management aimed at inter-regional or inter-sectoral allocation of multi-use natural resources such as water resources for agriculture, mining industry among others (Robinson and Gelhar, 1995; Mukherjee, 1996; Ianchovichina et al, 2001).

In the 1990s and 2000s the problems associated with petroleum resource utilization against crude oil price volatility and exhaustibility assumptions attracted CGE applications. A number of CGE based studies on the economies of resource producing countries have been conducted such as Benjamin et al, (1989) on Cameroon’s oil boom, and Decaluwé et al, (1990) on Tunisia.

However these models are static models and therefore fail to examine all relevant variables as well as the inter-temporal implications of policy decisions. A Dynamic CGE model has however been used by Ghadimi (2007) on Iran, and Omgba and Djiofack (2010) on Cameroon. Briesinger et al, (2009) and the World Bank (2010) conducted dynamic CGE modeling on Ghana’s management of petroleum revenues.

3.4.4 CGE Models and Fiscal Rules

Most of the literature on resource revenue management is concentrated in partial equilibrium models. But these models ignore relevant variables in an economy that interact with each other at the same time. They do not also cover inter-sectoral and the distributional effects of policy changes (Omgba and Djiofack, 2010). Analyses of the impact of fiscal rules require models that look at the economy-wide impact; hence, Ghadimi (2007) argues that a general equilibrium model is the ideal model for these analyses. General equilibrium models include Computable General Equilibrium (CGE), Overlapping Generations Model (OGM), Dynamic Stochastic General Equilibrium (DSGE) and the IMF's Global Integrated Monetary Fiscal Model (GIMF).

Robinson et al, (1999) developed a static CGE model implemented in GAMS to analyze the impact of capital inflow and the Dutch disease in Cameroon. They found that the Dutch disease had occurred in Cameroon and their results were consistent with the effect of the booming sector. They further found that the Dutch disease had implications for fiscal policy due to what they called "varying degree of tradability" and which was found to be an important factor in sectoral response to the boom of resources.

One of the most comprehensive works on fiscal rules is by Jafarov and Leigh (2007) in which they consider long-term fiscal policy options in Norway in relation to the substantial expected increase in pension outlays. They draw a comparison between Norway's current fiscal rules which set non-oil deficit to 4% of Government Pension Fund assets, and three alternative rules including the permanent income rule, growth-adjusted rule and asset-targeting rule. They also analyze the macroeconomic consequences of alternative fiscal rules by using the IMF's Global Integrated Monetary Fiscal Model (GIMF).

The results of the study show that the 4-percent rule and the three alternative rules considered here involve trade-offs in terms of covering the expected increase in pension spending, long-term fiscal sustainability, short-term expansionary impulses, intergenerational wealth transfers, and long-term output gains.

In terms of covering the expected pension increase in the long term, the growth-adjusted rule that saves more of the oil wealth than other rules come the closest to covering the pension increase. Moreover, this rule provides the least stimulus to the economy in the short-term and performs the best in terms of long-term growth. However, this rule also involves a much larger transfer of oil wealth for consumption by future generations.

Performance under the permanent income rule is close to the allocation of resources based on the growth-adjusted rule, but fiscal policy under this rule is very sensitive to assumptions of long-term oil prices, growth rate, and interest rate.

The asset-targeting rule avoids the much larger transfers, but it performs worse than the growth-adjusted and permanent income rules in terms of long-term growth and covering the pension increase in the long term. Moreover, this rule could be pro-cyclical. The 4-percent rule is pro-cyclical in the short-term and performs the worst in terms of long-term growth as well as covering the pension increase in the long term. However, their study does not explain how they calibrated their model to match the economy and is not clear how they account for population aging. They also assume that all agents are credit constrained which is consistent with DSGE models (Galaasen, 2009).

To fill in this gap, Galaasen (2009) repeated the study by Jafarov and Leigh (2007) on Norway, but changed some of the fiscal rules. The rules examined include the 4% Norwegian rule, growth-adjusted, constant tax wealth targeting and spending models. He used an Overlapping Generations to account for intergenerational issues based on demographic changes.

The study shows that the current 4% rule gives a short-to-medium term tax reduction and then followed by repeated tax increases into the long-term. Thus this rule is fiscally unsustainable because it allows intermediate tax cuts. The growth-adjusted and the constant tax rules show that reforms to the fiscal policy which allow for pre-funding through significant accumulation of government wealth in the short-run will prevent large tax increases. The rule therefore is consistent with a large distribution of welfare and incomes from future generations to the current adults and young ones.

The study by Galaasen (2009) has some weaknesses including the use of the Overlapping Generation Model which does not give true representative feature of the economy in a macroeconomic framework. Moreover, it excludes net immigration and focuses on mortality and fertility rates. The exclusion of immigration which is a feature of Ghana's economy for example makes the study inappropriate for countries like Ghana since immigration is an important feature of most developing countries.

Dagher et al, (2010) used a DSGE model to analyze alternative fiscal and monetary policy impact of oil windfalls in Ghana focusing on expenditure smoothing and expenditure composition for the fiscal side and on discretionary policy tightening and exchange sales reduction for the monetary side. The study differentiates between the short-run impact, associated with demand-related pressures, and the medium run impact on competitiveness and growth.

The study shows that the impact on inflation and the real exchange rate could be moderate, especially if the fiscal authorities smooth oil-related spending or increase public spending import content. However, a policy mix that results in both fiscal expansion and the simultaneous accumulation of the foreign currency proceeds from oil as international reserves would raise demand pressures and crowd-out the private sector. In the medium term, however, the negative impact on competitiveness as a result of 'Dutch Disease" effects could be smaller, provided public spending increases the stock of productive public capital. The findings of the study underscore how different policies could respond to the macroeconomic impact of oil boom.

3.4.5 CGE Models in Ghana

Alfsen et al, (1997) use a CGE model to describe an integrated economy–soil-productivity for Ghana, and through several simulated scenarios calculated the drag on the Ghanaian economy of soil mining and erosion, and illustrate the effects of different policies aiming at reducing these environmental issues. The model is complemented by an integrated tropical soil productivity module which touched on the impact of cultivation and management on the productivity of soil in the agricultural sectors. In their model the demand for agricultural land correspond to the production level while soil productivity is calculated to show the pressure on the forest reserves. The model treats activities in the Western region of Ghana, a region noted for significant mining, as separate sectors to particularly analyze the concern of deforestation in the growth process.

The long-run impact of fertilizer use is linked to improved vegetation cover which reduces erosion through the protection of the soil against heavy rain, and leaves more plant residues for recycling in the ground. The policy implications of fertilizer use was proved beneficial but only at the initial stages in order not to pollute water bodies when excessively used. On investments, they use 'structuralist' elements to model the capital market. Gross capital formation is allocated to manufacturing sectors and services by fixed base-year coefficients and that investments and sector-specific depreciation rates are important determinants of sectoral capital stock.

Colatei and Round (2000) use a SAM based CGE to model the effect of Structural Adjustments Programme on poverty levels. They examine the possible consequences of a range of poverty-alleviating income and/or consumption transfers on the economy of Ghana.

The study was done through the use of a previously-estimated SAM for Ghana, for the year 1993, which falls well within the reform era for the country. The study discounted earlier ones which used macro-meso models to analyse poverty effects of policies. In their work, they disaggregated income earners in Ghana into Savannah farmers, Forest farmers, Coast farmers, Savannah non-agricultural farmers, Forest non-agricultural farmers, Coastal non-agricultural farmers, Urban unskilled, Urban skilled, Accra skilled, and Accra unskilled. This demarcation is particularly significant to reflect the wide income disparity in Ghana. However, the model exhibits the possibility of substantial spillovers (and feedback effects) in terms of the targeted groups.

Arbenser (2002) analyzes the impact of foreign direct investments and policies that would increase these investments. The CGE model which follows Lofgren et al, (2002) provides that policies that increase the inflow of FDI as well as reduce tariff levels are important complementarities for enhancing economic growth and welfare.

What is particularly innovative in this model is the introduction of foreign capital inflow into the model. This affected some of the equations and thereby enriched modelling in Ghana’s economy. Foreign capital redefines the balance of payment equation as well as constitutes an income to the economy. However, he introduced foreign capital inflow as an exogenous variable which undermined the dynamism associated with capital flows. This is because foreign capital does not come in on its own. They are influenced by both domestic and foreign conditions which could ‘endogenize’ FDI inflows. There is therefore an important limitation in the model.

In a study on another important resource in Ghana, Cocoa, Briesinger et al, (2008) used a CGE model to evaluate the potential role of cocoa on the way to a middle income economy by 2015. They found that Ghana could reach a middle income status if it recorded strong growth in all sectors including cocoa. They estimated that cocoa production had to increase by 60,000 tons annually for a decade to generate the necessary growth for accelerating Ghana to a middle income status. They argued that value addition to cocoa in Ghana was lower than in its neighboring Ivory Coast, and that cocoa processing needed to be enhanced, but more importantly, a move towards diversification of the economy and the export structure would be appropriate.

Diao (2009) developed a quantitative assessment of the economy-wide impact of Highly Pathogenic Avian Influenza (HPAI) in Ghana under different scenarios. He used a dynamic computable general equilibrium model for Ghana based on 2005 Social Accounting Matrix with a detailed production structure at both national and sub-national levels.

The study examined the impact of lowering capital stock in chicken production and lowering marginal budget share for chicken consumption for the period 2009 and 2011 and concludes that the shock in chicken demand due to consumers’ anxieties about the flu is the dominant factor in causing chicken production to fall. He also states that a 40% reduction in chicken demand causes domestic production to fall more than 40 percent, with certain import substitutions. While he recognizes a fall in imports, the ratio of imports to total domestic consumption rises.

On the other hand, a 40% fall in chicken demand will reverse this. The model does not show any significant drop in chicken price at the new equilibrium with a much lower level of demand and supply. It however concludes that the economy-wide impact on GDP was insignificant. In reality, the effect on GDP might have been underestimated since chicken consumption is highly patronized in Ghana leading to the government imposing an import duty on it in 2010 to encourage the production and consumption of local chicken.

Also, Briesinger et al, (2011) developed a disaggregated dynamic general equilibrium model and used it to assess Ghana’s growth options in economic transformation placing emphasis on the role of agriculture and Green Revolution–type growth. They observe that past governments were too ambitious and unfocused, a development which has changed now and which helped the country to achieve a middle income status through political, institutional and economic reforms that supported rapid transformation in the economy.

They contend that economic transformation theory should be broadened to cover other important issues of distribution of wealth and the level of poverty, which had been ignored in the past. They further argue that agriculture and “homegrown” manufacturing sectors through private sector leadership were more likely to create and sustain job creation and poverty reduction. However, they also recognize the need for government involvement to be greater than what is required in the “Washington consensus” style of policy prescription. Government is required to create and promote an enabling investment environment whilst investing in institutional and physical infrastructure. One of the limitations of this study is that even though it recognizes the role of institutions in fostering economic transformation, the authors failed to incorporate the quality of institutional arrangements in the model.

The only studies so far on Ghana’s management of its petroleum revenues with CGE models particularly relating to issues of fiscal policy and fiscal rules are Breisinger et al, (2009) and the World Bank (2009).

Breisinger (2009) for example used a recursive dynamic CGE model to analyze the allocation options of petroleum in Ghana. They tested four scenarios in a CGE model: where all the revenue is channeled into the economy; where all the revenue is saved and interest earned is used for public investment; where oil revenue of only 5 percent of GDP is retained to support the budget; and finally where petroleum revenues are smoothed in and out over time. While the scenario of smoothing revenue in and out of the budget had the best outcomes on inequality, the poorest still face challenges of significantly improving on their living conditions. The study does not address the problem of how much should flow into the budget and what rules should guide the determination of fiscal benchmarks.

The shortcomings of this study is that it treats petroleum revenues as coming from natural resources fund saved abroad. This does not take into consideration the fact that in Ghana, there are two fiscal frameworks - spending and savings. Petroleum revenues that are not spent are saved. Thus, spending does not come from the natural resources fund saved abroad unless under two conditions, when there is a revenue shortfall and when the oil is depleted. Thus, the study is inconsistent with Ghana’s fiscal model. This is understandable because at the time of the study Ghana had not developed and passed the Petroleum Revenue Management Act in which the fiscal model is well defined.

The World Bank (2009) also used a dynamic CGE to look at broad allocation options of petroleum revenues in Ghana. Except the World Bank, all previous studies on Ghana’s oil boom do not take into consideration the level of oil reserves and rate of extraction in projecting petroleum revenues. They argue that the creation of an oil fund could be used to smoothen the economy against global commodity price volatilities but recommends that sound macroeconomic management should be strengthened, whiles inefficiencies and corruption are tackled. They state that clear rules about spending petroleum revenues in future are required. The study also recommends a substantial spending of petroleum revenues currently to enhance productivity in rural areas and in the agricultural sector. The study also fails to address the issues of fiscal rules that should guide government budgetary options for maintaining fiscal sustainability.

This study reflects the main features of Ghana's fiscal policy for guiding the management of petroleum revenues – higher early spending, creation of a Petroleum Fund, spending in productive sectors including agriculture to accelerate development. However, due to the fact that the study was conducted before the passing of Act 815, it does not empirically test the effects of the fiscal model. Moreover, existing CGE models in the literature are limited in several ways both in its theoretical composition and practical application to real world phenomena. The following are some of the limitations.

CGE models rely on one year's data to explain world phenomenon, which is quite over-simplistic and unrealistic. The base year is chosen by the researcher which ignores the rational behavior of human relying on past events to assess the future. Dynamic CGE models attempt to address this problem but always ignore the effect of pre-base year data. This makes CGE models very discretionary.

CGE models have been limited by their choice of model structure, parameters, and functional forms for analysis (Panagariya and Duttagupta, 2001). The parameters are derived from calibrations based on one year data, or are sometimes borrowed from other literature. Thus parameters are not estimated from statistical foundations of empirical data such as time-series data due to lack of sufficient and appropriate time series data especially in developing countries, which makes it difficult to model observed behavior of economic agents towards technological change, income growth and price changes among others (Barker, 2004).

The assumption about general equilibrium inherent in CGE models is also unrealistic. Steady state equilibrium may never be reached, because society tends to always find new ways of distorting or advancing the order of society through research, technology and development which put it in a never-ending process of change and disequilibrium. This makes the foundation of CGEs unstable (Scrieciu, 2006).

Also, the assumption that there is full employment in the economy is flawed. However, recent studies have tended to relax this assumption by introducing unemployment in the model. In this case, the factor market is cleared when the sum of all factor demand plus in addition to factors that are not in demand are equal to factor supply (Logfren et al, 2002). However, in countries like Ghana where data on unemployment is unavailable, this assumption may be understandably excused.

The zero homogeneity of demand functions coupled with the linear homogeneity of profits in prices are not adequate to explain the effects of prices especially absolute level of prices on equilibrium conditions (Shoven and Whalley, 1984). Also, the homogeneity assumption tends to generalize and homogenize completely different economies without taking account of country specific features (Scrieciu, 2006).

The theoretical framework of CGEs combines general equilibrium theory, neoclassical micro-economic optimization behaviour of rational economic agents, as well as some macroeconomic features to explain economic, social and environmental policies. This places the solution to all problems on the market. However, CGE models fail to account for the effects associated with fiscal efficiency and "institutional arrangements, ethical issues and the developmental needs of a society within an interdisciplinary, pluralistic, holistic, and dynamic approach" (Söderbaum, 2000).

Also, in spite of the recent attempts at introducing dynamic features into CGE models, these are limited in scope and form. For instance, CGE models that account for capital accumulation as a dynamic process is very silent on regulatory and institutional changes that an economy needs to be on the desired path to steady state equilibrium. The lack of incorporation of these dynamic features narrows the economy to an "artificial perfect macroeconomic stability" (Ackerman, 2005), which inadequately explains the adjustment path to equilibrium.

This study seeks to address the limitations of CGE models from accounting for institutional quality considerations in the analysis of policy decisions. This is also in recognition that the impact of fiscal rules must be measured from the perspective of fiscal efficiency. Fiscal efficiency requires that public spending optimizes the level of desired welfare outcomes. Thus it is important to incorporate the quality of institutional frameworks in a dynamic CGE model to assess the real impacts of petroleum revenues on the economy. This is particularly important because Ghana is associated with low absorptive capacity (World Bank, 2010).

CGE models that have been applied to issues of resource management particularly in oil producing countries (for example; Benjamin et al, 1989; Decaluwé et al, 1990; Ghadimi, 2007; Omgba and Djiofack, 2010; Briesinger et al, 2009; World Bank, 2009) all ignored the role of the quality of institutional frameworks in the management of these resources particularly in implementing fiscal rules. But Bigsten and Levin (2000) observe that the efficiency of government spending is an important determinant of growth, poverty and income distribution.

The regulatory and institutional gaps in CGE models therefore demonstrate an important gap in the literature on CGE models generally and in Ghana particularly. This important shortcoming is being addressed in this study through the incorporation of regulatory and institutional arrangements in a recursive dynamic CGE model for Ghana to determine the efficiency of the adjustment process of government fiscal decisions towards the desired levels of impacts on economic development.

3.5 Institutional Quality and Fiscal Rules

3.5.1 Relationship between Institutions and Economic Performance

The need for institutional quality consideration in models of economic development became necessary in the 1990s when the World Bank observed that the poor performance of its programmes in developing countries was attributed to factors other than those in conventional economic theory. This compelled the Bank to reconsider the efficiency of its operations in the developing world in what has been captured in the works of Nellis (1999). He argued that international organizations needed to support economic reforms through political and institutional mechanisms like the creation of strong administrative systems or legal structures capable of sustaining economic development. This in his view needed to be factored into the new theoretical model.

However, the definition of what is “institutional” introduces different approaches to the understanding of institutions, which thereby brings out the difficulties in forging consensus on the causal effect between institutions and economic growth. In spite of this, there is a general agreement that institutional theories provide opportunities for explaining the behavior of the economy at different levels and scope. This has led to the adoption of new perspectives on the usefulness of institutions in the theory of growth and development (Valeriani and Peluso, 2011).

In the early 1990s, many economists pointed out the links between institutional quality and economic development. Early studies of institutional quality relationship with economic performance focused on western societies.

Acemoglu, Johnson and Robinson (2001) explained that the sources of exogenous variation in institutions based on the types of the European colonization policies in the 19th century (and earlier). Two major colonial institutional policies were identified as examples of the source of this variation - the extractive policies and protective ones against the government expropriation. This made it possible for colonial institutions to continue having a hold in their former colonies.

Hall and Jones (1999) argue that institutional quality is a part of what they call “social infrastructure” which reflects the governance as well as the large capital level, and which shows the increasing productivity of workers.

Engerman and Sokoloff (1997) suggest that the institutional approach to attribute economic performance to governance is empirical, but they based their institutional effects to the prevailing conditions in the earlier era of colonization.

The literature on the effects of institutional quality has been extended to explain the relationship between natural resource abundance and economic development. This is part of the broader “resource curse” literature. As already stated in Chapter One, there is significant evidence that low growth performance in resource-rich countries is attributed to low institutional quality (Eifert et al, 2002; Mehlum et al, 2006; Humphreys et al, 2007).

The World Bank (2009) observes that political and institutional arrangements are the most important determinants of how countries with oil perform. The difference in the growth performance of resource-rich countries is primarily the result of how resource rents are distributed through institutional arrangement (Eifert et al, 2006) and countries that ignore the importance of these arrangements and have weak institutional environment will likely see their oil resources turned into a curse (Eifert et al, 2002).

Institutional quality perspectives are varied in the literature. The rent seeking theory suggests that in countries where there is large abundance of natural resources, there is also a high incidence that firms will tend to engage in rent seeking behaviour and leaving a few firms to engage in productive activities (Torvik, 2002). Rent seeking behaviour is often common with firms that operate in countries with low institutional quality (Lane and Tornell, 1996).

The absorptive capacity theory suggests that poor investment decisions largely associated with low absorptive capacity affect the transformative effect of abundant natural resources leading to low returns from investments (McMahon, 1997). In another study, it was found that "unproductive investment booms were evident in many countries" (Sarraf & Jiwanji, 2001). Similarly, Lal and Myint, (1996) attributed the poor results in investment impacts to a collapse in the efficiency of investment in resource-rich countries. This is particularly important for Ghana since most of the features of low absorptive capacity exist in the country (World Bank, 2010).

The statist theorist associate resource management with the type of governance regime in resource-rich countries. There is evidence of a positive relationship between growth and the political system with resource-rich countries usually aligned to oligarchies rather than democracies (Lal, 1995). These states have been able to avoid the curse of resources and Botswana and Malaysia have been cited as examples in the literature.

In contrast states that have not been able to avoid the curse are either "predatory state" or "factional state". Auty (2001) argues that dependence on primary exports of resources for any length of time leads to "predatory" and "factional governments" both of which are identified by poor management of the economy. Ghana is seen to be a grabber friendly country (World Bank, 2009), showing a factional democracy (World Bank, 2007; Booth et al, 2005; Eifert et al, 2002; Nugent, 1999); and there exist political incentives that have created a “high level of clientelism” (World Bank, 2007); and sometimes showing features of its past history as an autocracy (Eifert et al, 2002).

Most of these studies followed the methodology used in Sachs and Warner (2005) by applying cross-country Ordinary Least Squares (OLS) regression analysis which is limited in several ways. For instance, evidence from cross-country OLS has problems surviving the use of panel instrumental variable estimation techniques. Also, cross-country OLS does not take into account endogeneity, heterogeneity and omitted variables biases, which exist in empirical growth models (Islam, 1995).

However, Arellano and Bover (1995) and Blundell and Bond (1998) solved these problems by using a system Generalized Method of Moments (GMM) estimation method. This includes the regression equation in levels; and applied lagged differences of the endogenous variables as instruments. The results from these studies confirm that low institutional quality is strongly related to poor economic performance in resource-rich countries.

There are however divergent views on the strong positive effect of institutional quality and management of abundant natural resources. For example, Leite and Weidmann (2002) found in a study from 1970 to 1990 that there is no direct effect of low institutional quality of resource abundant countries on growth.

These results are confirmed by Sala-i-Martin and Subramanian (2003) and Isham et al, (2002) in their studies on the influence of natural resources on broader indicators of institutional quality. Nevertheless, they all agree that there exist indirect effects of low institutional quality on growth. Whilst Leite and Weidmann (2002), found indirect effects of institutional quality through corruption, Isham et al, (2002) and Sala-i-Martin and Subramanian (2003) found that resource abundance penalizes growth through institutional quality when the resources are "geographically concentrated".

In this apparent lack of consensus, this study conducts a test in this thesis on the development impact of resource abundance and the management of resource revenues (through fiscal rules) given a level of institutional quality, and using a different methodology based on a recursive Dynamic CGE model. Thus, the study in addition to addressing an important limitation of CGE models, will likely resolve the consensus problem in the literature on the effects of institutional quality in resource abundant countries.

3.5.2 Measurement of Institutional Quality

There are different measures of institutional quality in the literature. However, the literature on institutional quality measure is dominated by partial equilibrium models. Whilst most studies generate indicators and proxies to test hypotheses based on institutional quality (see, Knack and Keefer, 1995; Kaufman et al, 2004; Williams and Siddique, 2008), others have used data bases that include measures of institutional arrangements and which have stimulated empirical investigation of new research questions.

La porta et al, (1998, 2003) show through historical approach involving legal origins that good governance is correlated with economic growth. Their theory reflects the view held by Hayek (1960) who argued that checks and balances of the courts in the Anglo-American constitutions played a significant role in the judicial independence. They further suggest that judicial independence was associated with economic and political freedom which contribute to secure property rights, regulation (economic effects), democracy and human rights (political effects).

Several measures of institutional quality have been adopted in different empirical works. Acemoglu et al, (2001) used three institutional indices: *Voice and Accountability*, *Regulatory Quality* and the *Government Effectiveness* drawn from the six indicators proposed by Kaufman et al, (2003) called "*The World Bank Global Governance Indicators*".

Klein (2005) used the series from the data set based on the *International Country Risk Guide* published by the Political Risk Services (PRS) Group. The series are defined as; *Bureaucratic Quality, Control of Corruption in Government, Risk of Expropriation, Repudiation of Government Contracts and Rule of Law*. A higher value for any of the indicators shows a higher quality of an institution.

Valeriani and Peluso (2011) used three institutional indicators - *civil liberties*, *quality of government and number of veto players*. The index for *civil liberties* was adopted from the *Freedom House*. Freedom House is an independent watchdog organization which promotes the expansion of freedom around the world by promoting democratic change, monitoring freedom, and advocating for democracy and human rights. The index of the Freedom House is designed such that each country and territory is assigned a numerical rating on a scale of 1 to 7 towards a survey made up of 15 questions, with 1 rating representing the highest degree of freedom whilst 7 represents the lowest level of freedom. The ratings show the extent to which a country is classified as Free, Partly Free, or Not Free.

The index for *legislative checks and balances* is adopted from the *Political Institutions database* of the World Bank in which countries are scored depending on the number of players that can veto a law. In this index, the higher the score, the more checks and balances are provided by the legislative process and the stronger will the institution be. Just like Klein (2005), the index used to measure the *quality of government* is adopted by the *International Country Risk Guide*.

All these indices and measures of institutional quality are limited and specific to selected factors/indicators. They therefore fail the comprehensiveness test. The index that is broad and comprehensive for measuring the quality of institutions is the Country Policy and Institutional Assessment (CPIA) Index.

The CPIA has been used by the World Bank to influence allocation of assistance to the countries which are rated high (Dollar and Levin, 2004). Aid allocation is influenced by CPIA ratings because it involves capital inflows which cannot be managed with weak institutional quality.

Similarly, as capital inflows, petroleum revenues from the export of petroleum are efficiently transformed into growth and development when invested in an environment of high institutional quality. This is consistent with the evidence that good institutions are important for economic growth (Acemoglu et al, 2001; Rodrik et al, 2002).

The CPIA has been criticized by some researchers as a measure of institutional quality, but such criticisms only target the form and not the theoretical foundations of the index. For instance, it has been criticized for heavily relying on a uniform model of what works in development policy (Kanbur, 2005b) and therefore does not take into consideration country specific institutional diversity.

Similarly, Herman (2004) underlines the low ability of the CPIA indicators to discriminate among countries or over time. The index seeks to draw some comparisons between countries to determine allocation efficiency of aid and such analysis must be done with a common framework. However, although country specificities are important, it is practically impossible to factor all the different specificities into one model as most of these are qualitative and abstract.

Another criticism is that CPIA indicators are not outcome based. Beynon (2001), argues that it is difficult to monitor outcomes than policies, hence the over reliance of CPIA indicators on policies rather than outcomes makes it infeasible to analyze the effects of institutional quality. This argument is confirmed by Kanbur (2005) who states that the CPIA does not contain any final outcome variables like poverty, extreme poverty, etc.

Nonetheless, these arguments are simplistic and fail to appreciate that the CPIA cannot be inputs and outputs at the same time. Most of the studies which apply CPIA use it as input to generate outcomes, expressing the effects of policies on outcomes such as growth, development and poverty reduction, a methodology followed in this study.

There is also the criticism that the CPIA measures investors' perceptions of institutional quality based on a questionnaire filled out by World Bank personnel. Thus, domestic institutional quality is influenced by "the opinions of foreign investors about what constitutes a good investment climate". It is important to note nevertheless that this criticism has been addressed by the World Bank's commitment to country ownership of policies through the Poverty Reduction Strategy Papers (PRSP), a participatory process between debtor-country and the World Bank in which CPIA results serve as the main indicators on which the PRSPs are focused (Cage, 2009).

It is further argued that even though the CPIA has some limitations like all measures of institutional quality, it does cover extensively issues related to institutions and human capital development, which are accepted in the growth and development literature as important determinants of sustained growth, poverty reduction and effective use of development assistance (Ibid, 2009).

Empirical literature on growth shows that growth is influenced by policies such as macroeconomic stability (Fischer, 1993), rule of law (Knack and Keefer, 1995) and trade openness (Frankel and Romer, 1999); and these factors are all captured on the CPIA index. There have been specific studies that applied the CPIA index and conclude that it has positive impact on poverty reduction and economic growth (See Collier and Dollar, 2001; Easterly, 1999; and Burnside and Dollar, 2000).

CHAPTER FOUR

OIL REVENUE FORECASTING

4.1 Introduction

This chapter estimates petroleum revenues which are used in the computations and application of fiscal rules in chapter 5 and 7. There have been several forecasts of expected revenues from oil (World Bank, 2009; International Monetary Fund, 2009; Briesinger et al, 2009). These revenues are very critical to the economic development of Ghana considering the historical capital shortages experienced over the years leading to high fiscal deficits. Ghana needs short-term and long-term forecast of petroleum revenues for purposes of development planning, budgeting and long-term fiscal planning. The Jubilee phase one field has been in production since 2010 and has now been increased by Jubilee Phase 1A. There are other discoveries that have been announced and are being appraised notably; Tweneboa, Enyenra, Ntomme (now called TEN), and a Plan of Development has been approved by the Government of Ghana, with first oil from these fields expected in 2016. When these fields are brought on stream together with Jubilee, the country could get substantial revenues.

The forecasting of government’s entitlement is the more important as the government must be concerned about the limitation of its revenues by capital allowance, at least when all capital costs have not been fully recovered. This raises a number of complexities including for instance crude oil price and production volatility. Another complexity is the computation of petroleum income tax, provided for in the Petroleum Income Tax Law (PNDC Law 188).

The components of petroleum income tax such as deduction of operations cost and amortization of capital and interest expenses as well as carry forward losses are very important indicators of complex forecasting due to the differences in methodological design and interpretation by different stakeholders. The tax system does not provide for thin capitalization and there exist no regulations on transfer pricing, which are likely to underestimate the expected government revenues.

4.2 Forecast inputs

4.2.1 Production Volumes

Forecast of oil and gas production volumes is an important first step to take in oil revenue forecasting. Oil production volumes are dictated by several factors. These include the geophysical conditions of the producing wells, government extraction policy, and the level of capital financing of development.

Production volumes are also affected by the phases of production. All producing fields go through ramp up phase to plateau production phase and then to a decline phase and then exit. These factors make production volumes uncertain. Before oil production stage is reached, there is a discovery and if it is declared commercial based on an appraisal programme, a Plan of Development (PoD) is submitted to the Government for approval to allow for field development. The Plan of Development contains among others estimates of production volumes over the life of the project. The realization of these estimates may delay although upon maturity more oil could be recovered. There are also oil recovery enhancement programmes such as water and natural gas reinjection. The estimated production profile from all the proven discoveries is presented in Table 4-1.

Table 4-1: Oil Production Profile (2010 – 2030)

Item	**Jubilee**	**TEN**	**META**	**Other**	**Total**
Unit	**Oil Volume**	**Oil Volume**	**Oil Volume**	**Oil Volume**	**Oil Volume**
Unit	**Mmbbl**	**Mmbbl**	**mmbbl**	**Mmbbl**	**Mmbbl**
Total	482.52	336.02	160.68	384.91	1364.13
2010	1.18	0	0	0	1.18
2011	24.2	0	0	0	24.2
2012	32.85	0	0	0	32.85
2013	41.61	0	0	0	41.61
2014	41.61	0	0	0	41.61
2015	41.61	11.7	0	0	53.31
2016	39.64	36.5	0	0	76.14
2017	37.45	36.5	0	0	73.95
2018	35.37	36.5	10.14	0	82.01
2019	33.29	34.68	15.6	0	83.57
2020	29.21	32.85	15.6	27.05	104.71
2021	24.97	29.2	15.6	41.61	111.38
2022	20.81	25.55	15.6	41.61	103.57
2023	16.64	21.9	14.82	41.61	94.97
2024	12.52	18.25	14.04	41.61	86.42
2025	10.4	14.6	12.48	39.53	77.01
2026	8.32	10.95	10.92	37.45	67.64
2027	8.32	9.13	10.14	33.29	60.88
2028	8.32	7.3	9.36	29.13	54.11
2029	7.96	5.48	8.58	27.05	49.07
2030	6.24	4.93	7.8	24.97	43.94

Source: World Bank (2013) *Energizing Economic Growth in Ghana: Making the Power and Petroleum Sectors Rise to the Challenge*, Energy Group Africa Region June 2013.

From the Table 4-1, Jubilee ramps up to its peak in 2013 and assumes a plateau until 2015. Planned production from TEN commences in 2016 whilst META commences in 2018.

4.2.2 Crude Oil Prices

Crude oil price is another important input in revenue forecasting. There is no one crude oil price, hence different crudes have different value (or prices) which are determined by the location of its production, the quality of the crude, and the demand and supply conditions surrounding them. Crude oil price forecast has been very challenging as a result. This necessitated the development of marker prices which have historically documented data series. Some marker prices include the Brent, the West Texas Intermediate (WTI) and Dubai. In Africa, the most common marker is Bonny light of Nigeria. There are many ways of forecasting crude oil prices.

a. Estimating a time series data of the price of one of the marker crudes over a defined period;
b. Estimating an average price of one of the marker crude over a period;
c. Estimating the selling price of crude oil over time;
d. Estimating alternative price scenarios such as base price, high and low prices.

Estimating crude oil prices presents some challenges. On one hand, the use of estimated time series exposes the volatility in crude oil prices over time but these prices need to be smoothened for revenue forecasting. On the other hand, Ghana’s jubilee oil is bench-marked to the Brent and since it can either sell at a premium or a discount, the use of Brent does not solve the uncertainty problem; and further ignores the deviations between it and the sales price which could translate into significant revenues.

The simpler way to revenue forecasting is to use alternative price scenarios, a practice that has been accepted in conventional forecasting for planning purposes. In the Table below, gross petroleum revenues are estimated based on production volumes form the oil fields and an average annual crude oil price of US$90. This price is based on a seven year moving average price of crude oil.

Table 4-2: Gross Revenue based on Alternative Crude Oil Price Scenarios

Year	**Total Oil Volume (mmbbl)**	**Gross Revenue @$90/bbl (US$MM**
Total	1364.13	122771.7
2010	1.18	106.2
2011	24.2	2178
2012	32.85	2956.5
2013	41.61	3744.9
2014	41.61	3744.9
2015	53.31	4797.9
2016	76.14	6852.6
2017	73.95	6655.5
2018	82.01	7380.9
2019	83.57	7521.3
2020	104.71	9423.9
2021	111.38	10024.2
2022	103.57	9321.3
2023	94.97	8547.3
2024	86.42	7777.8
2025	77.01	6930.9
2026	67.64	6087.6
2027	60.88	5479.2
2028	54.11	4869.9
2029	49.07	4416.3
2030	43.94	3954.6

Source: Computations by Author

4.2.3 Petroleum Costs

Petroleum cost refers to capital and operational costs incurred in exploration, development and production of oil. In Ghana the bulk of the costs are borne by investors and are therefore required to recover the costs. Oil revenue estimates are largely affected by cost recovery but the Petroleum Agreements signed between the Government and its investing partners specifies expenses that can be classified as petroleum costs. Capital costs reduces government revenue through a number of ways –

a. Capital and operational costs are deducted for income tax purposes (they are tax deductable),
b. Additional Oil Entitlements (AOE) are based on investors rate of return, hence they are computed after the deduction of capital and operational costs,
c. The state is expected to pay the proportional development and operational costs in respect of its paid interest.

The Petroleum Agreements provide for the forfeiting of the state's future share of oil with interest if it defaults in meeting its cash calls. This therefore reduces the state revenues in both the short and long run. Petroleum costs could also create uncertainty in revenue forecasting. In the first place, there are no cost recovery limits in Ghana and this could reduce early government revenues. Second, there are no ring-fencing costing provisions in Ghana's law, hence profits in one project could be used to finance costs in another project. Third, during the period of cost recovery, the state share is less, but expands beyond the full recovery of costs. In the Table that follows, gross capital and exploration expenditure are presented.

Table 4-3: Gross Capital and Operational Costs in Ghana's Jubilee projects

Year	Total	Gross CAPEX	Gross OPEX
	Oil Volume		
	Mmbbl	US$MM	US$MM
Total	1364.13	17709.06	17460.3502
2010	1.18	2632.49	20.6
2011	24.2	822.07	139.5
2012	32.85	1583.83	317.14
2013	41.61	1270.67	325
2014	41.61	2000	327.381
2015	53.31	2800	590.376
2016	76.14	2100	694.234
2017	73.95	1200	704.965
2018	82.01	1000	814.2845
2019	83.57	1050	819.0415
2020	104.71	850	916.7223
2021	111.38	400	912.570642
2022	103.57	0	901.9306093
2023	94.97	0	889.5147218
2024	86.42	0	877.4955063
2025	77.01	0	860.9669453
2026	67.64	0	845.8306341
2027	60.88	0	838.1112526
2028	54.11	0	831.3149722
2029	49.07	0	824.5380966
2030	43.94	0	815.5565612

Source: Ghana National Petroleum Company

4.3 Ghana's Upstream Petroleum Fiscal Terms

The fiscal regime is defined by the Petroleum (Exploration and Production) Law of 1984, and the Petroleum Income Tax Law of 1987 (PITL), but the negotiated terms are contained in a Petroleum Agreement. The fiscal regime has major elements and minor elements. The major elements which form the basis of the revenue forecast are royalties, participating interest, corporate income tax and additional oil entitlement (AOE).

a. **Royalties**: Ghana's model petroleum agreement sets royalties between 2.5 and 12.5% for crude oil and gas. PNDC Law 84 states Clause 20(1):

"There shall be payable to the Republic royalty in respect of any petroleum produced in Ghana, except as may otherwise be provided in accordance with the terms of a petroleum agreement."

However, the royalty rate has been negotiated in different Petroleum Agreements, with Agreements following the jubilee discovery providing for higher royalties than pre-jubilee agreements. The following Table 4-4 shows variability in fiscal terms by different agreements.

Table 4-4: Differential Fiscal Terms by Petroleum Agreement

CONTRACT	YEAR	ROYALTY	INITIAL INTEREST	ADDITIONAL INTEREST
VANCO	2002	5%	15%	NIL
KOSMOS	2004	5%	10%	2.5%
HESS	2006	4%	10%	3%
TULLOW	2006	5%	10%	5%
VITOL	2008	12.5%	10%	10%
AFREN	2009	10%	10%	15%
CHALLENGER	2009	10%	10%	15%

Source: Ghana Petroleum Agreements (Various)

For this study, the forecasting is based on the two Jubilee Agreements - the West Cape Three Points and Deepwater Tano blocks - in which a negotiated 5% royalty is provided. The Government can decide to take royalty in kind or cash. According to the Petroleum Agreements, where the government decides to take in cash, the contractor shall pay to the Government the weighted average market price of crude oil at the given period. For the Jubilee operations, the Government of Ghana has elected to receive in-kind royalties which means its royalty income will come from the sales of the oil lifted.

b. Participating Interest: The participating interests of parties to a petroleum license are defined by law or Agreement. However, while investors' interest may vary depending on the number of investors, the state's participating interests are mostly fixed by Petroleum Agreements. Jubilee is being developed and produced as a unitized production area on the basis of a 50/50 split between the Deepwater Tano and West Cape Three Points licenses. The Unit Operating Agreement however provides for redetermination of the original hydrocarbon in place which is likely to slightly change the tract participation of the partners on the two blocks. In the original Jubilee Unit license for instance, the net participating interest of the Government of Ghana, which has been used to compute the 'government take' in production equivalents is presented below.

Table 4-5: Ghana's Participating Interests

Interest/Cost	Deepwater Tano Block	West Cape Three Points Block	Jubilee Unit
Initial Interest	10%	10%	10%
Additional Interest	5%	2.5%	3.75%
GNPC Share of:			
Net Oil Production (after royalties)	15%	12.5%	13.75%
Operating Costs	15%	12.5%	13.75%
Exploration Costs	0%	0%	0%
Development Costs	5%	2.5%	3.75%

Source: Ghana Petroleum Agreements (Various)

Participating interest of the Government of Ghana are two types under the current Petroleum Agreements – the initial interest which is free and carried through development; and additional paid interest which the GNPC can take upon commercial discovery, which is paid for but carried through exploration.

Participating interest has been progressive in Agreement after agreement as the country matures as an oil producer. Even though the forecast of "Government Take" is based on the Jubilee Agreements, it is important to note that when oil is discovered based on Agreements with higher royalty rates, the state's share of oil will increase and revenues will be more significant (See Table 4-4).

The Government of Ghana through the GNPC pays its capital and operational costs in respect of its paid interest but operational costs particularly at the production level are paid for all its interest. For the purpose of this forecasting, the total participating interest of the Government of Ghana is 13.6% including a free carried interest of 10%. The Agreement further provide that where the GNPC fails to finance its paid participation, the Contractors would pre-finance and recover the default amount from GNPC's future share of oil with interest. This is often called a "collateralization clause".

c. Petroleum Income taxes: The Petroleum Income Tax Law (PNDC L 188) sets petroleum income tax at 50%. However this is negotiable. In all the Petroleum Agreements signed between the Government of Ghana and International Oil Companies, the petroleum income tax has been negotiated to 35%. The tax is a percentage of the chargeable income on any petroleum operations. The chargeable income is composed of gross sales revenue less royalties, operating costs, capital allowances, interest expenses, and losses carried forward from previous years. The capital allowances are also calculated by depreciating all exploration and development costs on a five-year straight-line basis which begins with the year the expenditure is incurred or alternatively the year of the commencement of the project, whichever is later. In Section 11 of the Petroleum Income Tax Law (PNDC Law 188), Companies are required to file quarterly returns and based on the assessment by the Ghana Revenue Authority or upon self-assessment, the right amount due the state is assessed and paid.

d. Additional Oil Entitlement: The fiscal regime provides for a progressive resource rent tax, known as Additional Oil Entitlement (AOE), to assure that the country captures a progressively larger share of the profit from successful projects. The AOE is tax on the investor's inflation-adjusted rate of return at certain thresholds which are defined by a Petroleum Agreement.

4.4 Forecast Methodology

4.4.1 Spreadsheet Modelling

In this study, the Spreadsheet Model is used to forecast petroleum revenues. This method is simple and straight forward. On the spreadsheet, different inputs are modeled and their relationship with each other is established. The modeling can either be done in the columns or rows in which revenue streams, costs, and production volumes are all displayed. It is also transparent as it could be interpreted by any user of spreadsheet. Models can also be developed for different projects or integrated into one project. In this study, all the producing and planned production wells are either on the West Cape Three Point Block or Deep Water Tano, having almost the same owners; and it is therefore convenient to integrate the model. Also, as indicated earlier, there is no cost ring fencing in Ghana's oil and gas industry. The real challenge arises when production volumes from other blocks are factored into the estimate. In this case, different models must be developed for different projects and the revenues consolidated thereafter.

4.4.2 Main Assumptions

The forecasts are based on the following assumptions.

a. The period of revenue projection is 2010 – 2030.

b. Estimated total oil production annually are from all proven reserves – Jubilee, Tweneboa-Enyenra-Ntomme (TEN), Mahogany-Teak-Akasa (META), Other (estimated from the satellite projects of Jubilee and TEN), in millions of barrels. This is based on production volume data provided by the GNPC.

c. Estimated Gross revenues based on three price scenarios – base case scenario of $90 per barrel of oil, high case scenario of $110 per barrel and a low case scenario of $70 per barrel. This captures the effect of price volatility on revenues. Gross revenues are estimated as total oil production volume multiplied by crude oil price.

d. Estimated royalty is at an average of 5% based on the Petroleum Agreements with the Oil Companies; which is deducted from gross revenue to obtain gross revenues after royalty.

e. Estimated gross capital cost and operational costs are given as provided by the GNPC. These are deducted from post royalty gross revenues to obtain net revenues or profit oil equivalent.

f. Estimated revenue for state participation is at 13.75% of net revenues and is deducted from net revenues to obtain Investors Take.

g. Corporate income tax is calculated at 35% (as indicated in the Petroleum Agreements) on Investors profit. For some years, corporate taxes were not due as a result of capital allowance and carry forward losses. Ghana does not have cost recovery limits.

h. Government petroleum revenues are arrived at by the sum of royalties, state participation and corporate income taxes where applicable.

Table 4-6 shows computations of the components of the fiscal regime at the base case scenario of $90 per barrel. Government petroleum revenues are the summation of Royalty, Government participation, and corporate income tax. This excludes other statutory taxes paid by the Oil Companies to the state, which are excluded from petroleum revenues by the Petroleum Revenue Management Act 815.

Table 4-6: Estimation of Oil Revenue by Revenue Stream (US$MM)

Year	Royalty @$90/bbl (0.05)	Gross Rev minus Royalty	Revenue after royalty	GOG @$90/bbl (0.1375)	Investor	Corp Tax (0.35)	Corp Tax Due	GOG REVENUE (US$90/bbl)
Total	6138.585	116633.1	81463.7	11201.259	70262.445	24591.855	24591.86	41931.7003
2010	5.31	100.89	-2552.2	-350.9275	-2201.273	0	0	5.31
2011	108.9	2069.1	1107.53	152.28538	955.24463	334.33562	-1866.93	261.185375
2012	147.825	2808.675	907.705	124.8095	782.89556	274.01345	-1592.92	272.634438
2013	187.245	3557.655	1961.985	269.77294	1692.2121	592.27422	-1000.65	457.017938
2014	187.245	3557.655	1230.274	169.16267	1061.1113	371.38896	-629.26	356.407675
2015	239.895	4558.005	1167.629	160.54899	1007.08	352.47800	-276.78	400.443988
2016	342.63	6509.97	3715.736	510.9137	3204.8223	1121.6878	844.9056	1698.44926
2017	332.775	6322.725	4417.76	607.442	3810.318	1333.6113	2178.517	3118.73386
2018	369.045	7011.855	5197.5705	714.66594	4482.9046	1569.0166	3747.534	4831.2444
2019	376.065	7145.235	5276.1935	725.47661	4550.7169	1592.7509	5340.284	6441.82597
2020	471.195	8952.705	7185.9827	988.07262	6197.9101	2169.2685	7509.553	8968.82052
2021	501.21	9522.99	8210.4194	1128.9327	7081.4867	2478.5203	2478.520	4108.66301
2022	466.065	8855.235	7953.3044	1093.5794	6859.725	2400.9038	2400.904	3960.54812
2023	427.365	8119.935	7230.4203	994.18279	6236.2375	2182.6831	2182.683	3604.23091
2024	388.89	7388.91	6511.4145	895.31949	5616.095	1965.6333	1965.633	3249.84274
2025	346.545	6584.355	5723.3881	786.96586	4936.4222	1727.7478	1727.748	2861.25863
2026	304.38	5783.22	4937.3894	678.89104	4258.4983	1490.4744	1490.474	2473.74545
2027	273.96	5205.24	4367.1288	600.48020	3766.6485	1318.327	1318.327	2192.76719
2028	243.495	4626.405	3795.0900	521.82488	3273.2651	1145.6428	1145.643	1910.96268
2029	220.815	4195.485	3370.9469	463.5052	2907.4417	1017.6046	1017.605	1701.9248
2030	197.73	3756.87	2941.3134	404.4306	2536.8828	887.90899	887.9099	1490.06959

Source: Computations by Author

The petroleum revenues forecasted are used only for the computation of fiscal rules. This provided the basis for determining the fiscal benchmarks under alternative fiscal rules – the permanent income, bid-in-hand and Ghana's fiscal rules. The fiscal benchmarks were also used in the CGE model to assess the development impacts of fiscal rules.

4.4.3 Forecast Sensitivity

Petroleum revenues are influenced by a number of factors. These factors which introduce volatility in Government petroleum revenues are; petroleum costs, production volume, crude oil prices and petroleum fiscal terms such as royalty rates, income tax rate and participating interest. In this study, sensitivity of government revenues to crude oil prices has been computed. Government revenues are based on 7-year moving average price of Jubilee Oil according to the Petroleum Revenue Management Act 2011. However, since data on jubilee does not cover 7 years, Government revenues are based on conservative estimates of crude oil prices. For this purpose, Government revenues are estimated by three oil price scenarios starting with a base case scenario of $90 per barrel, a high price scenario of $110 per barrel and a low price scenario of $70 per barrel. From Table 4-7, the high price scenario reflects in higher government revenues, whiles the low price scenario reflects lower revenues. For instance in 2012, an increase in crude oil price from $90 per barrel to $110 per barrels accounts for an increase in government revenue by 20%. Similarly, a decrease in price from $90 per barrel to $70 per barrel sees a decrease in government revenue by 20%.

Table 4-7: Sensitivity Results of Alternative Crude Prices

Year	**Oil Production**	**US$90/bbl**	**US$110/bbl**	**US$70/bbl**
	(mmbbl)	**US$MM**	**US$MM**	**US$MM**
2010	1.18	5.31	6.372	4.248
2011	24.2	261.185375	313.42245	208.9483
2012	32.85	272.634438	327.16133	218.10755
2013	41.61	457.017938	548.42153	365.61435
2014	41.61	356.407675	427.68921	285.12614
2015	53.31	400.443988	480.53279	320.35519
2016	76.14	1698.44926	2038.1391	1358.759409
2017	73.95	3118.73386	3742.4806	2494.987089
2018	82.01	4831.2444	5797.4933	3864.995519
2019	83.57	6441.82597	7730.1912	5153.46078
2020	104.71	8968.82052	10762.585	7175.056414
2021	111.38	4108.66301	4930.3956	3286.930404
2022	103.57	3960.54812	4752.6577	3168.438493
2023	94.97	3604.23091	4325.0771	2883.384728
2024	86.42	3249.84274	3899.8113	2599.874195
2025	77.01	2861.25863	3433.5104	2289.006901
2026	67.64	2473.74545	2968.4945	1978.996362
2027	60.88	2192.76719	2631.3206	1754.213755
2028	54.11	1910.96268	2293.1552	1528.770145
2029	49.07	1701.9248	2042.3098	1361.539837
2030	43.94	1490.06959	1788.0835	1192.055674
Total	1364.13	41931.7003	50318.04	33545.36024

Source: Computations by Author

CHAPTER FIVE

FISCAL RULES AND FISCAL SUSTAINABILITY IN GHANA

5.1 Introduction

Fiscal rules have become important tools for managing the allocation of resource revenues for development and have been used increasingly by different countries. Fiscal sustainability measures have also been used to determine what the fiscal constraint countries are faced with and to guide policy formulation aimed at sustaining consumption in future.

The literature on 'resource curse' gained prominence in the 1980s following the collapse of the economies of resource-rich countries years after the oil boom of the 1970s. Most of the studies were concerned about the impact of crude oil volatility until the 2000s when issues of resource depletion re-emerged.

Earlier theories of resource depletion were formulated by Hotelling (1931) and those who followed him such as Solow (1974) and Hartwick (1978). Hotelling for instance argues that the optimal path of resource extraction where the markets are competitive requires that resource prices net of the marginal cost of extraction grow with interest rates. For the monopolist, he explains that the net marginal revenue, and not the net price, will grow at the interest rate. The results by Hotelling were based on assumed constant marginal cost of extraction. This ignored the effects of cumulative production (Devarajan and Fisher, 1982). This brought about the debate whether to leave natural resources underground which could lead to what is called 'scarcity rent', a future gain to the resource owner (Hamilton, 2009).

Solow (1974) was concerned about the allocation of resources to meet intergenerational concerns based on a per capita constant consumption. Hartwick (1978) followed Solow's argument and contends that the value of productive investments in natural resource-rich countries should always be equal to the value of the resource rents.

The re-emergence of the exhaustibility theory departed from the ‘scarcity rent’ argument. Rather than leave resources underground, the current literature is concerned about sustainable management of resource benefits along a sustainable consumption path. Thus, the PI rule has gained prominence in the literature.

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The measurement of fiscal rules in resource-rich countries has often targeted a design and application of rules that prevent these countries from the phenomenon of “resource curse”, in which natural resource wealth translates into poor economic performance.

The re-emergence of the exhaustibility theory departed from the ‘scarcity rent’ argument. Rather than leave resources underground, the current literature is concerned about sustainable management of resource benefits along a sustainable consumption path. Thus, the PI rule has gained prominence in the literature.

In this study, Ghana’s fiscal rule for allocating petroleum revenues to the budget is compared with the permanent income rule and the bird-in-hand rule to assess fiscal sustainability in Ghana’s emerging oil economy in which it is faced with the sustainable use of its oil wealth for development.

5.2 Defining Alternative Fiscal Rules

5.2.1 The Permanent Income Rule

The Permanent Income rule requires that a permanent proportion of oil wealth is spent annually to sustain consumption by maintaining a constant real expenditure path beyond the lifetime period of oil reserves.

Ossowski and Barnett (2002) provided a good mathematical foundation for the permanent income consumption. They show that PI ensures long term fiscal sustainability in resource producing countries. They analyze welfare maximization as the primary objective of government consumption decision and assume that fiscal policy decisions are independent of other macroeconomic factors that are exogenous. They define the government consumption decision as:

$$B_t = RB_{t-1} + G_t - Z_t \tag{1}$$

Where B_t is government debt at the end of the period; R is the interest rate (assumed constant); G_t is primary government expenditure; and Z_t is petroleum revenues. They also assume certainty in the flow of petroleum revenues; hence petroleum revenues are constant over the field life. With constant government expenditure $(\bar{G})$ and non-oil revenue (T_t) they define the PI as the returns on the present discounted value of resource wealth presented as:

$$\overline{G} = T_t + \frac{r}{R}\sum_{i=0}^{N} R^{-1} Z - rB_{t-1} \qquad (2)$$

Where N is the oil field life and t is current period.

Leigh and Olters (2006), extend this theory by introducing habit formation. They argue that the adjustment in consumption decision reflects the habits of planning authority which then determines the budget constraints. Their formula for PI is expressed in ratio to non-oil GDP as follows:

$$g^* = \left(1 - \frac{\alpha}{R}\right) . \left[\tau + \frac{r-\gamma}{R} . \sum_{s}^{N} \left(\frac{1+\gamma}{R}\right)^{-s(-t)} . z_s - \frac{r-\gamma}{1+\gamma} . b_{t-1}\right] + \frac{\alpha}{R} . g_{t-1} \qquad (3)$$

where g^* is the ratio of spending to non-oil GDP; $R = 1+r$; r is long run interest rate assumed constant; τ is ratio of non-oil revenue to non-oil GDP; z is ratio of oil revenue to non-oil GDP; α is habit strength; γ is non-oil growth rate, b_{t-1} is ratio of previous period debt levels to non-oil GDP. The introduction of habits is influenced by the notion that consumption behaviour depends on previous behaviour. Thus, consumption is addictive and therefore the level of spending in the previous year is equal to the stock of habit in the current year (Leigh and Olters, 2006). In this case the reaction of policy makers to adverse shocks over time is to spread the policy adjustment over a number of years (Velculescu, 2004). They also assume a constant non-oil GDP growth which is assumed further to be lower than interest rate if the question of sustainability is to be achieved.

However, Maliszewski (2009) argues that such a policy would mean transferring positive non-oil income growth in per capita terms from future generations to the current generation since the present value of future non-oil revenue flows is usually higher than that of current petroleum revenues and therefore the rule has limited practical relevance.

The role of uncertainty in government consumption was accounted for by Engel and Valdes (2000) and applied by Maliszewski (2007). They show that due to large volatilities in crude oil prices, petroleum revenues are faced with great uncertainties. Hence previous models that ignored uncertainty are only applicable to non-stochastic cases. They introduced uncertainty mainly because of large fluctuations in prices. The above optimizing rules are derived for a non-stochastic environment, and need to be adjusted to take this uncertainty into account. They argue that if oil production remains constant, and prices follow the following process:

$$\log P_t - \mu = \psi(\log P_{t-1} - \mu) + v_t \quad (4)$$

where v_t is a normally distributed shock with variance σ^2_{v} and Price P_0 has mean $\mu_{\mathrm{p},0}$ and variance $\sigma^2_{\mathrm{p},0}$ whiles the initial production has $\mu_0 = \mu_{\mathrm{p},0}\mathrm{Q}$ and variance $\sigma^2_0 = \sigma^2_{\mathrm{p},0}\mathrm{Q}$, then Government maximizes consumption at:

$$g_0(\sigma_0^2, \sigma_v^2) \approx [1 - \Delta_{BU} - \Delta_{IU}]g_0(0,0) \quad (5)$$

where $g_0\ (0,0)$ is the optimal PI level of consumption with no uncertainty whiles Δ_{BU} and Δ_{IU} are functions of σ^2_0 and σ^2_{v}. Therefore if the uncertainty emerges, it reduces government's optimal consumption. There is an inverse relationship between levels of uncertainty and government consumption.

This study adopts the formula for the Permanent Income model as defined in Ossowski and Barnett (2002). That is equation 2 above. Recall the formula for measuring the permanent budget constraint:

$\bar{G} = T_t + \frac{r}{R}\sum_{i=0}^{N} R^{-1}Z - rB_{t-1}$

Where G_t is primary government expenditure

B_t is government debt at the end of the period

R is the interest rate (assumed constant) and $R = 1 + r$, where r is the nominal interest rate.

T_t is non-oil revenue

Z_t is petroleum revenues

Assuming certainty and constant government expenditures, hence petroleum revenues are constant over the field life; the optimal government consumption is a combination of tax revenues (non-oil revenues) and the present value of future petroleum revenues. Total revenues per year are a net of interest on debts. This formulation has been followed to define the other fiscal rules.

5.2.2 The Bird-in-Hand Rule

This rule requires the government to spend interests on financial assets from the investments of petroleum revenues. As explained by Bjerkholt and Niculescu (2004), in this rule, the government turns its oil resources into financial assets and only spends the projected returns on the financial assets each year.

In this case, since petroleum revenues are invested in financial assets, the optimal decision will cover the present value of expected returns on expected financial assets. This can be expressed as follows:

$$\bar{G} = T_t + \frac{r}{R}\sum_{i=t}^{N} R^{-1}rF + rB_{t-1} \qquad (6)$$

Where F is expected accumulated financial assets and;

rF = returns on Financial Assets

But; $F = PF_{t-1} + rPF_{t-1} + Z_t$ (7)

Where PF_{t-1} = Balance from previous years Petroleum Fund

rPF_{t-1} = returns on previous years balance in the Petroleum Fund

Z_t = Current year petroleum revenues

Thus beyond oil depletion, the government sustainable consumption is reduced to the continuous returns on the financial assets. This may not be significant during the period of oil production and therefore implies transferring significant current transfers to future generations when the financial assets would have accumulated.

5.2.3 The Ghana Fiscal Rule

The Ghana Petroleum Revenue Management Act 2011 (Act 815) provides a spending model which requires heavy current spending and lesser savings. The two major components of the model are; budget support and investments in financial assets. The rule provides that a maximum of 70% of annual petroleum revenues less the equity financing cost of the national oil company (referred to as "benchmark revenues"), shall be transferred to the budget and shall be known as the "Annual Budget Funding Amount", whiles the remaining 30% shall be saved in the Petroleum Funds (the Stabilization Fund and the Heritage Fund). This is however applicable during the period of oil production. However, after oil depletion, the ABFA shall be equal to the real returns on financial assets of the Petroleum Fund. Thus, the Ghana rule has components of a 'big-push' and the Bird-in-hand rules. Therefore, in the period of oil production, the government consumption decision is expressed as:

$$\bar{G} = T_t + Z_{tb}(1-0.3) + rF - rB_{t-1} \qquad (8)$$

But $Z_{tb} = Z_t - GNPC =$ Benchmark Revenue

GNPC is share of annual petroleum revenues, and; $rF=0$, because oil depletion has not been reached and it is therefore not spent. Also, the Stabilization Fund is spent when there is revenue shortfall. However, when oil is depleted, the Annual Budget Funding Amount shall not exceed the real returns on financial assets of the Petroleum Fund. Thus, the Government consumption will be:

$$\bar{G} = T_t + rF - rB_{t-1} \qquad (9)$$

In the oil revenue projections, it is assumed that oil reserves will not be completely depleted by 2030. Also, the GNPC, the National Oil Company, is allocated part of the revenue through the budgetary process to pay its equity costs and make new investments. In the past two years, the average allocation to the GNPC is about 47% of total revenues. This will likely reduce to about 20% when the development costs are retired by 2021. The balance which is left for spending and savings is referred to as the Benchmark Revenue. Thus, the fiscal rule used in this analysis is expressed in equation 8 above. The following sections show the results of the analyses of fiscal rules and fiscal sustainability.

The equations above were used to measure fiscal rules based on the following assumption:

a. Estimation of Government non-oil revenues (T). This data was sourced from the Ghana Statistical Service.
b. Estimation of petroleum revenues (Z) computed by Author from data sourced from the GNPC (See Chapter three for oil revenue forecasting).
c. Government Debt levels (B) sourced from the Bank of Ghana
d. Discount rate (r) for discounting the value of petroleum wealth over estimated field life cycle was assumed to be 3%.
e. GDP data was sourced from the Ghana Statistical Service
f. It was also assumed that the Government spent (G) all its non-oil revenues.

Therefore the difference between government expenditure (G) without petroleum revenues and that with petroleum revenues was determined by the type of fiscal rule applied. The estimated Government Expenditure with petroleum revenues based on the Permanent Income rule is presented in the following Table 5-1 (See Appendices 1-B and 1-C for computations of the Bird-in-hand rule and the Ghana rule).

Table 5-1: Computation of Permanent Income Value (Scenario 1 - $110/bbl; r = 0.03)

YEAR	Oil Rev (US$MM)	Non-Oil Rev (US$MM)	PI (Expenditure With petroleum Revenues) (US$MM)	Petroleum Rev (PI) (US$MM)	PI(%GDP)
2010	6.372	4946.501329	5523.012236	576.5109064	0.141861
2011	313.4225	8278.185221	8278.195221	576.5109064	0.147232
2012	327.1613	9677.650933	10254.16184	576.5109064	0.168386
2013	548.4215	11979.26312	12555.77403	576.5109064	0.176592
2014	427.6892	14060.78125	14637.29216	576.5109064	0.175271
2015	480.5328	16395.31293	16971.82384	576.5109064	0.17411
2016	2038.139	18545.54383	19122.05474	576.5109064	0.174091
2017	3742.481	20996.91551	21573.42641	576.5109064	0.174449
2018	5797.493	23726.13517	24302.64608	576.5109064	0.17457
2019	7730.191	26578.53192	27155.04283	576.5109064	0.17473
2020	10762.58	29788.38292	30364.89383	576.5109064	0.174779
2021	4930.396	33434.3816	34010.8925	576.5109064	0.174627
2022	4752.658	37618.51889	38195.02979	576.5109064	0.17447
2023	4325.077	42370.30209	42946.813	576.5109064	0.174249
2024	3899.811	47772.54313	48349.05404	576.5109064	0.173982
2025	3433.51	53920.95203	54497.46294	576.5109064	0.173735
2026	2968.495	60926.2596	61502.77051	576.5109064	0.173513
2027	2631.321	68916.70509	69493.216	576.5109064	0.173317
2028	2293.155	78040.95376	78617.46466	576.5109064	0.173086
2029	2042.31	88615.85512	89192.36602	576.5109064	0.172882
2030	1788.084	100686.5208	101263.0317	576.5109064	0.172662

Source: Computations by Author

5.3 Measurement of Fiscal Sustainability in Ghana

Fiscal sustainability is interchangeably used with sustainable consumption in some of the literature. Fiscal sustainability is derived from the potential destabilizing impact of resources on the short and long-term perspectives of the economy. Also, fiscal sustainability focuses on availability of revenues beyond resource depletion point whilst sustainable consumption is concerned about what to spend the revenues on to increase social welfare.

Resource revenues introduce substantial volatilities in the budget while the value of resource wealth is subject to interest rates which are also volatile. More so, resource revenues could be temporary and may not contribute to welfare volatility. The management of resource revenues must take into consideration current fiscal policy and future fiscal targets. Resource revenues must be managed with the long-term fiscal objectives. They can either harm long-term fiscal impacts or sustain the critical fiscal space for appropriate fiscal adjustments. It is therefore important to consider alternative options of fiscal rules that can sustain fiscal policy without sacrificing social welfare.

Fiscal rules are used to measure fiscal sustainability benchmarks on which the Government determines its short to long-term fiscal policy direction. This can be compared with the non-oil primary fiscal balance to determine alternative fiscal policy choices towards achieving fiscal sustainability. The analysis of fiscal sustainability is seen from two perspectives. The first is Government budget including petroleum revenues and the second is petroleum revenues as additional budget sources.

5.3.1 Fiscal Sustainability – the case of Government Budget with Petroleum Revenues

The main question that continues to confront resource-rich countries is by how much to increase consumption such that consumption can be sustained beyond the production profile.

Sustainable consumption is interlinked with fiscal sustainability. Thus, the fiscal rule that provides revenue allocation for relatively higher levels of spending over a longer-term is defined as the most fiscally sustainable.

The indicators for determining fiscal sustainability are varied. In this study, the ‘non-oil primary fiscal balance (NOPB)’ is adopted. It is an important guide to the long-term fiscal sustainability of fiscal policy. It includes non-oil revenues and non-oil expenditure. Invariably, it excludes all petroleum revenues, oil related expenditure and net interest payments. Interest receipts and payments are not under the control of the government but are dictated by capital market movement. This measure of fiscal sustainability is the most appropriate because of its comparison against long-term fiscal benchmarks based on inter-temporal government wealth. All the fiscal benchmarks are expressed in percent of non-oil GDP.

The Government budget at any given time consists of non-oil revenues and petroleum revenues. The petroleum revenues allocated to the budget depend on the type of fiscal rule. Given non-oil revenues, the additional fiscal space provided by petroleum revenues provides room for increasing government consumption. The major question confronting resource-rich countries is the political economy issue of spending all their resource revenues or part of it.

The danger in consuming all petroleum revenues is that it raises the consumption level during the period of oil production and lead to early enhancement of welfare. However, there cannot be sustained welfare since the petroleum revenues deplete beyond a certain level. This could raise social tensions especially if citizens begin to see a decline in social services as a result of depleted petroleum revenues.

There are several fiscal policy choices the Government must make if it is to avoid the dangers associated with managing a post oil economy. First, if the Government wishes to smoothen consumption and sustain welfare levels, it may have to resort to borrowing and create more fiscal deficits which then impose more burdens on the economy.

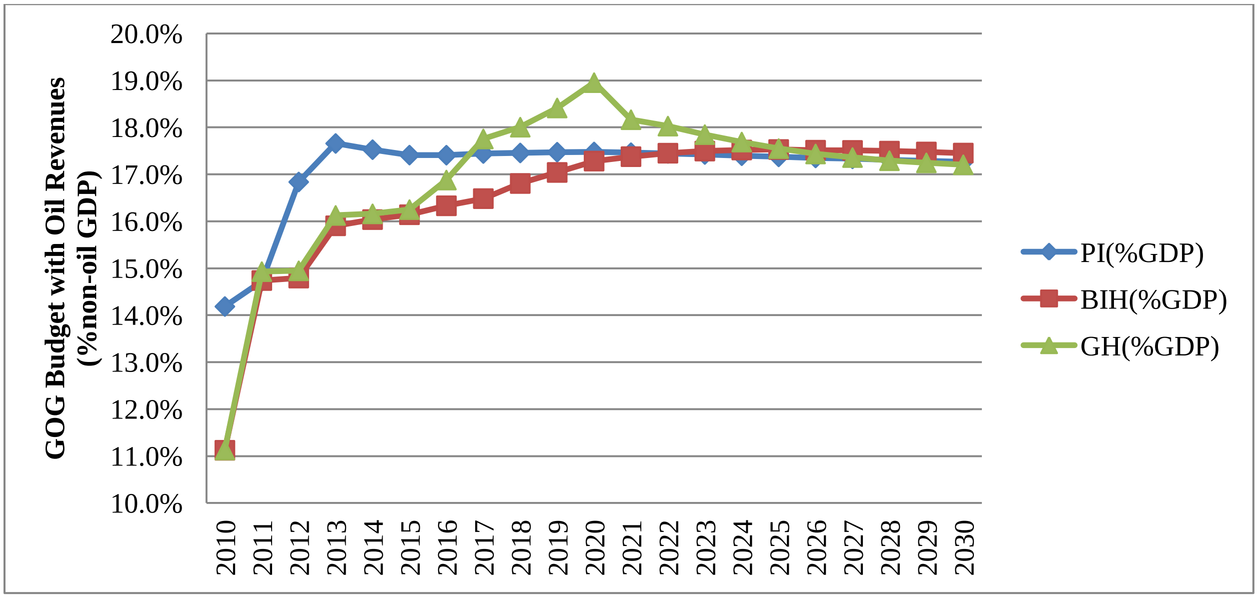
Second, Government must ensure that petroleum revenues do not go to pure consumption but are be invested in the productive sectors to create growth and improve on welfare levels. This is more sustainable since the growth of the productive sectors could continue to fuel the economy beyond oil depletion.

Third, Government must adopt a combination of fiscal rules and investment options such that a proportion of petroleum revenues are consumed or invested in so far as they do not sacrifice future liquidity requirement in a post oil economy. These fiscal rules could ensure sustained welfare and avoid the negative impacts on the economy of crude oil price volatility and exhaustibility of oil and gas resources. The Government of Ghana's preference for a rule reflects the last observation, but whether this rule could sustain consumption over a long-term horizon needs to be examined.

The long-term perspective must be borne in mind in the design of fiscal rules for developing countries. Thus, the fiscal rules explored in this study have all taken into consideration the long-term horizon of the consumption path. Solow (1974) states, "Someone… must always be taking the long view. They (sic) must somehow notice in advance that the resource economy is moving along a long path that is bound to end in disequilibrium of some extreme kind. If they do notice it, and take defensive actions, they will help steer the economy from the wrong path toward the right one".

In terms of fiscal sustainability, the total government consumption including oil induced consumption as a proportion of GDP shows that consumption could be sustained at different levels. For instance the bird in hand rule promises relative sustainability because it offers the highest government consumption levels proportional to GDP after oil depletion period compared to the permanent income rule and Ghana's fiscal rule. The permanent income rule offers higher early consumption whilst Ghana's rule provides higher consumption during peak oil production.

Figure 5-1: Sustainability of Government Consumption with petroleum Revenues (%non-oil GDP)



Source: Computations by Author

From Figure 5-1, Ghana's fiscal rule appears less sustainable in government consumption from petroleum revenues, as less revenues are relatively available to meet consumption needs in the long-run.

Naturally, most developing nations prefer to spend and invest their resource revenues to develop the country faster. Many of these countries are faced with capital shortages and high infrastructure financing gaps; and it makes no sense to save substantial revenues while living on the income from financial assets. It is recommended therefore that for those countries, investing in human capital and physical assets through a front-loaded approach could ensure high current benefits without sacrificing inter-temporal benefits as well (Takizawa, 2004; Solow, 1986; Hartwick, 1977). This is the popular Hartwick rule.

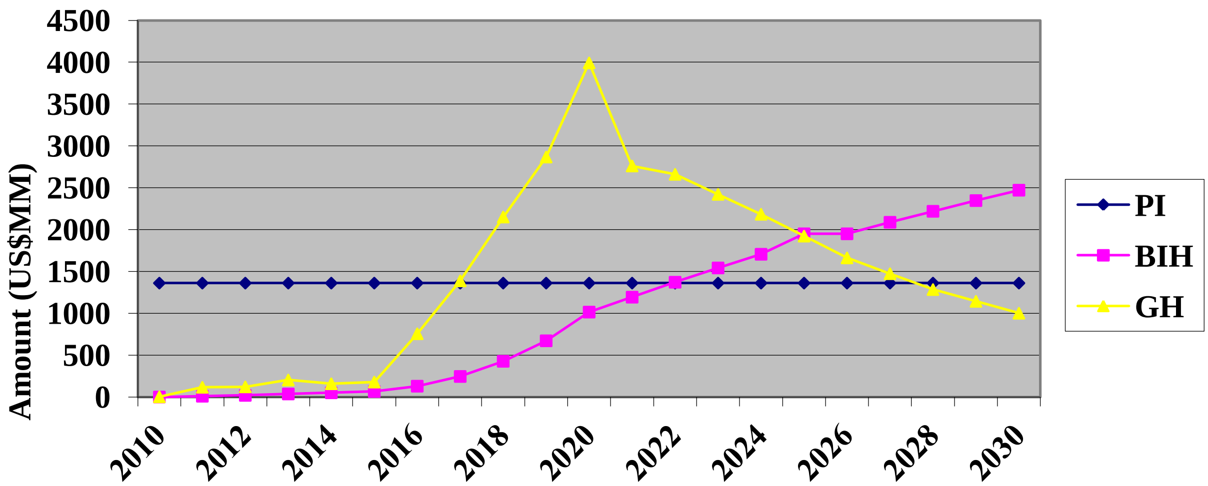
According to Hartwick, sustainability of consumption rests on investing resource rents such that the value of investment does not deviate from the value of resource rents at each point in time (Hartwick 1977; Solow 1986). Thus, genuine savings should be kept at zero at each point in time. Also, Van der Ploeg and Venables (2008) advocate an increase in current consumption which will raise income levels but also building on the capital stock for accelerating economic growth.

There are problems with the Hartwick rule however. One way this could affect the economy adversely is the significant fall in standards of living in future. In addition, the contributions of petroleum revenues to the GDP falls so much that it slows down growth. Both the permanent income and Ghana's rules are faced with low absorptive capacity of the economy which makes it difficult to efficiently spend heavily in the early years of production. However, if petroleum revenues are invested efficiently in the productive sectors rather than on recurrent consumption, the growth of the economy could sustain standards of living in future. Therefore, the Hardwick rule is plausible as a rule for sustainable development unless there is a mechanism to build on the institutional capacity to invest resources efficiently.

5.3.2 Fiscal Sustainability – the Case of only petroleum Revenues as additional Budget Sources

The analysis is a comparison of the long-term fiscal sustainability of the permanent income, bird-in-hand and Ghana's rules. From the following graph, a comparison of the fiscal rules show that spending of petroleum revenues based on Ghana's rule picks up slowly as oil production remains low, and ramps up to higher level of spending during peak production. Thus, as production and revenues increase, more revenues are allocated for spending. This however declines significantly in line with declining production.

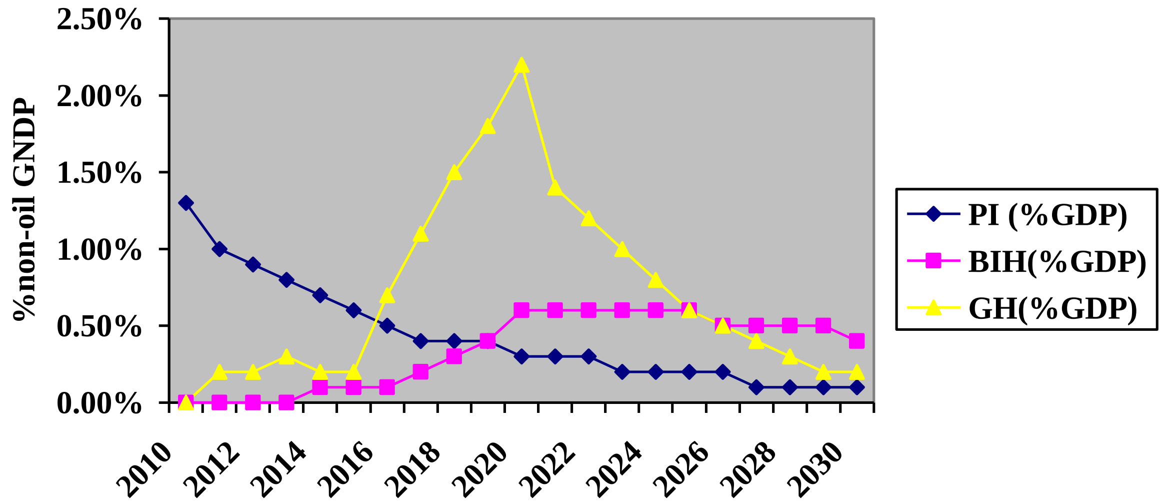
Figure 5-2: Oil Revenue Allocation based on alternative Fiscal Rules



Source: Computed by Author

Both the bird-in-hand and permanent income rules show that during the declining production phase and after oil depletion, relatively higher spending can be afforded from petroleum revenues but the bird-in-hand rule offers higher spending. The sustainability of these rules nevertheless depends on a number of factors including the size of the GDP.

Figure 5-3: Sustainable Fiscal Balance (%non-oil GDP)



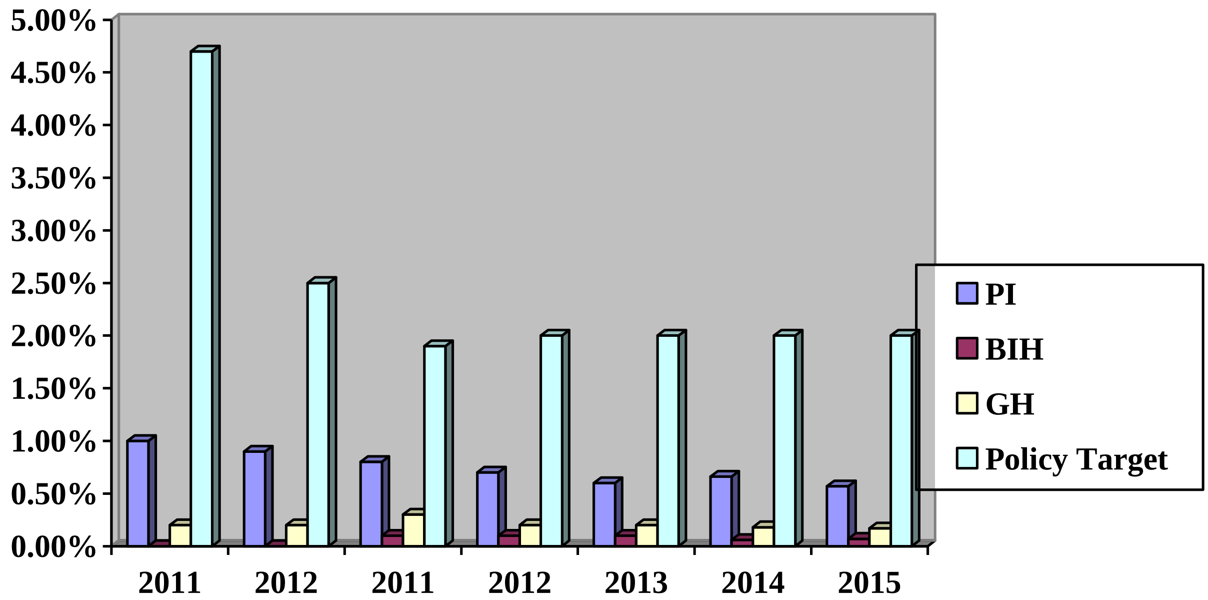
Source: Computation by Author

In Figure 5-3, both the Ghana rule and Permanent Income rule can finance relatively higher non-oil fiscal deficits in the short-to-medium term than their counterpart Bird-in-hand rule. However, in the long-term and especially after oil depletion, the Bird-in-hand can allow for higher fiscal adjustments. The adoption of Ghana's rule does not only reduce the ability of petroleum revenues to finance higher deficits in the long-run, but also narrows the future fiscal space in the economy with serious implications for financing sustainable consumption.

5.3.3 Can petroleum Revenues Finance Planned Government Fiscal Balance?

In this section, the medium term fiscal policy of the Government which defines the target fiscal balance for the period 2011 – 2015 compares with alternative fiscal balances based on Ghana's fiscal rules, the Permanent Income and Bird-in-hand rules.

Figure 5-4: Government Medium Term Fiscal Target Versus Fiscal Rules (%non-oil GDP)



Source: Computation by Author. For the policy fiscal deficit target (See IMF Article IV Consultations on Ghana (2011))

Petroleum revenues are expected to support fiscal sustainability but the current level of spending under Ghana's fiscal rule cannot fully absorb the deficit of 12% of GDP for the year, 2012. The permanent income ruler comes closer in the medium term. However, the variance between the medium term target and the permanent fiscal constraint shows that Government must reduce its spending to sustainable levels as determined by the new petroleum revenues. Contrary to this, Government will resort to debt financing of the deficit which undermines long-term fiscal sustainability.

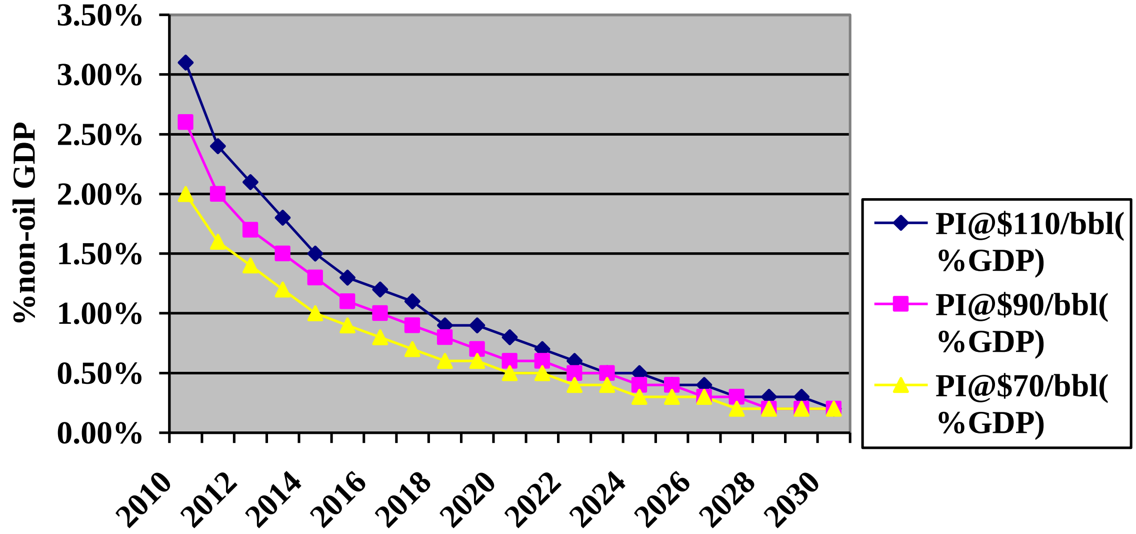
Historically, fiscal deficits have been financed by a mix of financing options. In 2012 for example, net foreign financing was about 11% of total deficit and 0.5% of GDP, whilst net domestic financing was 49.5% of total deficit and 2.4% of GDP. Thus, Ghana's deficit financing puts more pressure on domestic sources, which could therefore crowd out the private sector and undermine production and economic growth. Hence, the need for petroleum revenues to provide fiscal relief that reflects sustainable deficits cannot be understated.

5.4 Sensitivity Analysis

Sensitivity analysis is conducted to test the robustness of the computations. In a sensitivity analysis, the study shows that fiscal policy reflects changing economic conditions, domestic and global. The analysis covered changes in crude oil prices and the discount rate. Changes in crude oil prices affect Government's revenues from the export of oil which leads to changes in the amount of revenues a country receives from oil exports. The higher the price the more revenues received assuming production volumes do not fall, and the reverse is true. The practical manifestation of this has been demonstrated in the Government of Ghana 2011 Supplementary Budget in which expected revenues for the year was revised from the original budget. At $70 per barrel of oil in the original budget, annual petroleum revenues were estimated at GHS580 million which was revised to GHS1,250 million in the supplementary budget based on a crude oil price of $100 per barrel. However, actual revenues received in the year was GHS660 million.

One of the major problems facing resource-rich countries is the volatility of crude oil prices and petroleum revenues. Applying the Permanent Income rule and assuming a baseline crude oil price of US$90 per barrel of crude oil, a rise in oil price from US$90/bbls to US$100/bbls increases petroleum revenues, hence fiscal sustainability of the permanent income rule is improved. The permanent income line as percentage of non-oil GDP shifts to the right side of the baseline.

Figure 5-5: Sensitivity Analysis of Change in Crude Oil Prices – Permanent Income Rule



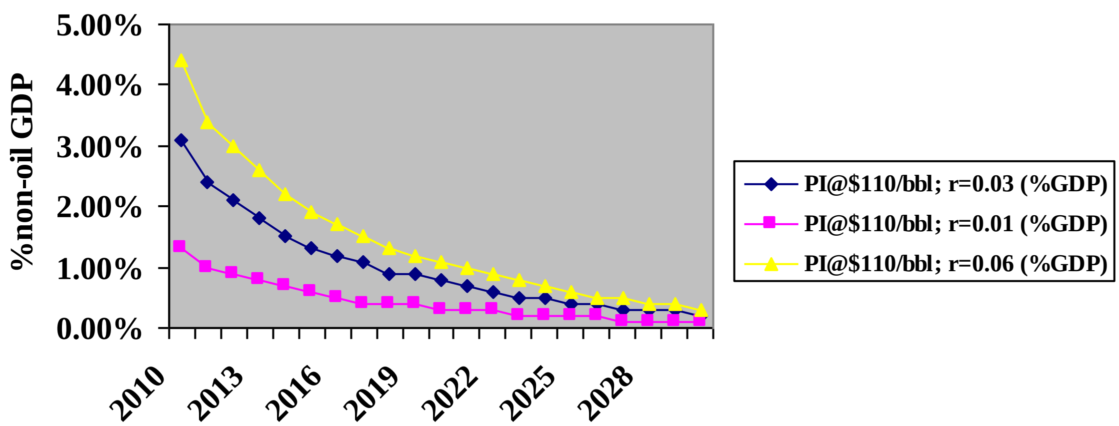
Source: Computations by Author

On the other hand, a fall in crude oil price to US$70/bbls reduces the fiscal sustainability of the permanent income rule. Thus, it has been established that changes in crude oil prices could support or undermine the fiscal efforts of Government. In this case, fiscal sustainability is improved or worsened depending on the direction of price movement. Further, where oil prices fall, the Government would have to resort to other financing options to reduce its fiscal deficit. This is done usually through borrowing from domestic and foreign financial institutions or the Government Treasury Bills, which in turn increases the debt profile, weakening the sustainability of fiscal rules in the process.

When crude oil prices recover, the temptation is usually to spend heavily as a result of the fiscal space created for the Government to operate within. Governments have the appetite for heavy spending where there is fiscal indiscipline and where there are no binding fiscal constraints because there is fiscal space created to reduce future deficits.

Oil rich countries that have managed their economies well have relied on countercyclical fiscal policy to accommodate the effects of price volatility. The fiscal instruments that have been used with varying impacts include the establishment of stabilization Funds, introduction of automatic stabilizers in fiscal policy, Fiscal Responsibility legislations and hedging, among others. In Ghana, the fiscal rule provides for a percentage of petroleum revenues to be transferred to the Stabilization and Heritage Funds to cushion against revenue shortfalls and for future generations respectively. The demonstration of counter cyclicality is borne out of the percentage allocation to the two Petroleum Funds in which 70% of the savings are transferred to the Stabilization Fund and the remaining 30% to the Heritage Fund.

Figure 5-6: Sensitivity Analysis of Change in the Discount rate – Permanent Income rule



Source: Computations by Author

Real interest rate is an important measure of petroleum wealth because returns on financial assets could determine fiscal sustainability based on fiscal rules. The fiscal rules that are particularly affected are the Permanent income and the Bird-in-hand rules which involve savings of petroleum revenues. Thus the impact of returns on investments depends largely on the type of fiscal rule. As can be seen from Figure 5-7, based on the permanent income rule, a higher return on investments (r = 6%) is associated with improved fiscal sustainability by increasing the sustainable non-oil deficit. If returns on investments is reduced to 3%, the sustainable non-oil balance line shifts to the left, indicating lower levels of fiscal sustainability.

One major problem facing developing countries such as Ghana is the lower returns on investments facing them in the domestic economy. Practically, most resource-rich countries that operate petroleum funds invest in foreign economies especially in the developed and emerging economies. Thus, the baseline analysis in this study was based on real interest rate of 3%, quite close to the realized returns on Ghana's Petroleum Funds.

Interestingly, in the last 2 years (2011 and 2012), Ghana had to move the investments of its petroleum funds from US treasury to Euro clear bonds due lower returns on US bonds arising from the global financial crises which has affected US markets greatly. In the first half of 2012 for instance, returns on the Alaska Permanent Fund stood at 0.2% whilst returns on the Ghana Petroleum Funds for the same period was 2.3%. Thus, resource-rich countries consider movements in the real interest rate on their investments an essential requirement for determining the sustainability of resource revenue induced fiscal rules.

5.5 Conclusion

The analysis in this chapter show that oil revenue horizon from the existing discoveries is not longer than twenty (20) years, hence temporary. Therefore fiscal rules in this situation must be designed to meet fiscal sustainability objectives. Among the three fiscal rules examined – the Permanent income rule, the bird-in-hand rule and the Ghana rule, the most fiscally sustainable is the bird-in-hand rule. Thus, the Ghana fiscal rule is not fiscally sustainable relative to the alternative rules. However, Ghana's short to medium term fiscal objective cannot be financed by any of the rules. The rule that comes closer is permanent income. Thus, the Government must cut down on spending to sustainable levels in order to prevent serious fiscal shortages in the long-term.

Further, Government would have to take a number of fiscal policy decisions to address the short, medium and long term fiscal issues that have the tendency of weakening the economy.

First, fiscal discipline and prudence for the effective management of financial assets especially if rules based fiscal policy is implemented. The growth of financial assets faces uncertainty as a result of the volatility in capital markets. Savings are adversely affected by financial crises, social disorders and unpredictable natural disasters (World Bank, 2006). Financial crises could particularly plunder returns on financial assets and slow down the growth of the petroleum funds which puts fiscal sustainability in danger. It is therefore important to institute a convenient combination of savings and investment rules that allow for investment of revenues in productive infrastructure while saving some of the revenue in low risk assets.

Second, social welfare volatilities associated with rising and falling consumption pattern are likely to increase social disaffection (Karl, 2007a). While the permanent income and Ghana rule may be preferable in the short to medium term because of its high level of consumption, their long-term sustainability is quite limited. In this case, where an early "big-push" fiscal policy is adopted with the possibility to generate long-term growth and additional non-oil revenues, it would be important to "gradually adjust the sustainable non-oil deficit benchmark as the impact of investment on non-oil growth becomes clearer" (Medas and Zakharova, 2009).

Third, the solution to the problems of social disaffections associated with fiscal sustainability policy rests with the political economy of managing natural resources (Ross, 2010; Karl, 2007b). Good governance, transparency and accountability are very critical. These principles ensure that citizens have reliable information about petroleum revenues, they participate in the spending or consumption decision and there is increased public accountability for the decisions collectively made. Price fluctuations may not necessarily bring about policy failure but lack of information on projected resource revenues and past expenditure pattern even more makes policies fail (Karl, 2007b). The Government must therefore involve the people and ensure greater understanding among them of the implications of heavy current consumption versus future consumption or vice versa. This could limit social disaffections for the Government and the burden it puts on the economy.

One way to reduce fiscal deficits and restore fiscal sustainability is to reduce the country's wage bill which has increased substantially following the implementation of the Single Spine Salary Structure, aimed at reducing income distortions and disparities in the formal sector. Another way is to reduce the level of subsidies in the utilities by allowing the petroleum deregulation policy and the Automatic Adjustment Pricing of public utilities to work without government interferences. The country's high election year spending must also be reviewed to avoid volatility in the adjustment to fiscal sustainability.

Finally, there is the tendency to rely on fiscal sustainability without addressing the structural causes of inefficiency and wasteful public spending. Government must control spending and improve on the efficiency of public spending by instituting far reaching public sector reforms. In order words, fiscal sustainability should not compromise the development objectives of spending oil and gas revenues. It is therefore important for the Government to adopt a fiscal rule that is not only fiscally sustainable but also provides greater development outcomes. The next two chapters present the estimation and analysis of the development impacts of fiscal rules and to establish if there is any relationship between the two.

CHAPTER SIX

A COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR GHANA

6.1 Introduction

To assess the impact of fiscal rules on the economy, a Recursive Dynamic Computable General Equilibrium (CGE) model is developed. This follows previous models used to study the impact of petroleum revenues on the economy of Ghana. However, the model has been modified to adequately provide empirical answers to the research questions.

6.2 Description of the Model Structure

The Recursive Dynamic CGE is developed along the neoclassical models developed in Dervis, de Melo, and Robinson (1982) and also follows the model developed by Logfren et.al (2002) to analyze the economy-wide effects of policies in developing countries. The Mathematical presentation of the model is adopted from Briesinger et al, (2011) but modified to capture elements suitable for the study.

The model analyzes the economic behavior of four institutional sectors: firms, households, the government sector and the foreign sector. All economic agents are assumed to adopt an optimizing behavior conditions under relevant budget constraints. The model is a multi-sectoral one which solves for variables such as commodity and factor prices at the same time and through endogenous process. The model also shows economic activities on demand and supply sides.

On the supply side, it assumes constant-returns to scale technology with constant elasticity of substitution (CES) aggregation function between primary inputs. There are three primary factor inputs in the model; labour, capital and land. Apart from labour and capital, intermediate inputs are also required to produce each sector's output. These make the formulation a two level production where at each level, capital and labour produce the real value added, which, in the next level are combined with intermediate inputs to produce output according to fixed input-output coefficients.

For the substitution between primary and intermediate inputs in the production functions, a Leontief technology is assumed. For commodities that are sold domestically and for exports, a Constant Elasticity of Transformation (CET) function is applied, while for commodities that have both domestic and foreign supply, an Armington Constant Elasticity of Substitution (CES) is used.

Labour is mobile across sectors but capital is fixed and sector specific. Another important assumption is the diminishing marginal efficiency of investment or public spending. There is also assumed full-employment in the economy; hence labour supplied is equal to labour demand. In this model we further assume a diminishing marginal efficiency of investment due to the problem of absorptive capacity and incorporate costs of adjustment for capital stock and institutional quality index.

On the demand side, household consumption is allocated across different commodities (market and home commodities) in line with Linear Expenditure System (LES) demand functions, solved from maximization of a Stone Geary utility function with a Cobb-Douglas utility function specification.

In this case, the marginal budget share of each good consumed is different from its respective average budget share (Briesinger et al, 2009). Income generated from the primary factors employed in the production process is the dominating income source for household consumers. Incomes from abroad through remittances or the government in direct transfers are also considered in the model.

On the government side, the model assumes a Cobb-Douglas aggregator function with endogenous taxes. Savings and Investments are endogenously determined.

In the foreign sector, commodities are tradable but capital and labour are not. We assume a small open economy such that the country does not have influence on world prices of imports and exports. The exchange rate is flexible.

In this model, there are notational conventions. Subscripts and superscripts i and j denote sectors and are in lower case. Scalars, parameters, time and data are also in lower case, variables and their initial levels and equation names are in capital letters, equation names begin with EQ, and initial values of variables and parameters are indicated with Z added to their names. The mathematical explanations of the equations are presented as follows.

6.3 Model Equations

There are different notational issues. Endogenous variables are Upper-case Latin letters without a bar. Exogenous variables are Upper-case Latin letters with a bar. Parameters are Lower-case Latin letters (with or without a bar) or lower-case Greek letters (with or without superscripts). Set indices are Lower-case Latin letters as subscripts to variables and parameters. The equations are presented as follows. However, the definitions of the variables and parameters are presented in Appendices 2-B and 2-C.

a. Price Block

The price block covers equations with endogenous model prices linked to other prices (endogenous or exogenous) as well as non-price model variables. Prices include import prices, export prices, demand price of domestic non-traded commodities, activity price, aggregate intermediate input price and consumer price.

Import Price

$$PM_{cr} = pwm_{cr} \; . (1 + tm_{cr}) \, . \; EXR + \sum_{c' \epsilon CT} PQ_{c'} . \; icm_{c'c} \qquad \text{(C1)}$$

The import price is in a local-currency unit and is defined as the price paid by domestic consumers for imported commodities. This includes the world price of imports, adjusted to foreign exchange rate and import tariffs plus transaction costs.

For all commodities therefore, the market price which domestic commodity demanders pay is the composite price, PQ; which applies only to payments for trade inputs. In the model, there is one equation for every imported commodity.

In the import price, both the exchange rate and the domestic import price are flexible, but tariff rate and the world import price are fixed due to the small-country assumption.

Export Price

$$PE_{cr} = pwe_{cr} \, . \; EXR - \sum_{c' \epsilon CT} PQ_{c} \; . ice_{c'c} \qquad \text{(C2)}$$

The export price is in local currency units and is the price domestic producers receive for the sale of their output in export markets. The export price is the world export price adjusted to exchange rate plus transaction costs. The difference between the export and import prices is that in the export price domestic consumers of the export commodities are not affected by the tariffs and transaction costs. The absence of tariffs and costs of trading reduces the price domestic consumers pay for the commodities.

Activity Price

$$PA_{a} = \sum_{c \epsilon C} PXAC_{ac} \, . \; \theta_{ac} \qquad \text{(C3)}$$

This is the gross revenue per activity unit and is defined as the return from selling the output or outputs of the activity. Where there are several activity commodities, the activity price becomes the sum of each activity price multiplied by the activity output.

Aggregate Intermediate Input Price

$$PINTA_a = \sum_{c \epsilon C} PQ_c \ .ica_{ca} \qquad \text{(C4)}$$

This input price ($PINTA_a$) shows the cost of disaggregated intermediate inputs per unit of aggregate intermediate input, and depends on composite commodity prices, PQ_c, as well as intermediate input co-efficient(ica_{ca}).

Activity Revenue and Costs

$$PA_a \ . \ (1 - ta_a) \ . \ QA_a = PVA_a \ . \ QVA_a + PINTA_a \ . \ QINTA_a \qquad \text{(C5)}$$

In this equation, each activity requires that total revenue net of taxes are fully used for payments for value-added inputs (QVA_a) and intermediate inputs ($QINTA_a$). In Ghana, oil activity is aggregated into mining and quarrying as part of overall industry activity. Revenues from oil activity are used for the payment of inputs in the development of oil fields and operational expenses. Taxes from oil activity including royalty are treated as Government revenues used to finance development infrastructure.

Consumer Price Index

$$cpi = \sum_{c \epsilon C} PQ_c \ . \ cwts_c \qquad \text{(C6)}$$

The *CPI* is fixed and functions as the numéraire in the basic model version. This is required because the model is homogeneous of degree zero in prices, hence if the value of the numéraire is doubled, all prices would also double but quantities remain the same.

b. Production and Trade Block

This consists of four categories:

a. Domestic production and input use;

b. The allocation of domestic output to home consumption, the domestic market, and exports;

c. The aggregation of supply to the domestic market (from imports and domestic output sold domestically); and

d. The definition of the demand for trade inputs that is generated by the distribution process.

In line with the competitive market assumption, activities are assumed to maximize profits subject to their technology, given prices (for their outputs, intermediate inputs, and factors). The CGE model includes the first-order conditions for profit-maximization by producers. Thus, in the technology nest, the activity level is either a CES or a Leontief function of the quantities of value-added and aggregate intermediate input use. A CES function is a generic function, but if the elasticity of substitution becomes zero, the function becomes a Leontief function. On the other hand, if the elasticity of substitution of a CES function is 1, the function becomes a Cob- Douglas function. In this model, the preference is the CES.

Apart from factor inputs, intermediate inputs are also required to produce each sector's output. This makes the formulation a two level production where at each level, capital and labour produce the real value added which, in the next level are combined with intermediate inputs to produce output according to fixed input-output coefficients.

The optimal mix of intermediate inputs and value-added constitute a function of the relative prices of value-added and the aggregate intermediate input. The level of activity determines the quantity of outputs produced by each activity. The exponent in the activity equation is a transformation of the elasticity of substitution between value added and the aggregate intermediate input.

Value-Added and Factor Demands

$$QVA_a = \alpha_a^{va} \cdot \left(\textstyle\sum_{f \epsilon F} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-p_a^{va}}\right)\text{-}1/p_a^{va} \qquad \text{(C7)}$$

In this equation, the quantity of value-added is a CES function of disaggregated factor quantities for each activity. Each activity demands factor inputs (QF_{fa}) at the point where the marginal cost is equal to marginal revenue or that the value of marginal product of each factor input is equal to its price. In this case, the zero profit condition is achieved. Put differently, where the marginal cost is total cost, it is equal to total revenue.

Factor Demand

$$WF_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot QVA_a \cdot \left(\textstyle\sum_{f \epsilon F} \delta_{fa}^{va} \cdot (\alpha_{fa}^{vaf} \cdot QF_{fa})^{-p_a^{va}}\right)\text{-}1$$

$$\cdot\ \delta_{fa}^{va} \cdot (\alpha\alpha_{fa}^{vaf})^{-p_a^{va}} \cdot (Q_{fa})^{-p_a^{va}-1} \qquad \text{(C8)}$$

In the demand for factor equation, the exponent p_a^{va} is a transformation of the elasticity of factor substitution. If this elasticity is higher, then the optimal change in the ratios of different factor quantities becomes larger in its response to relative factor prices. In this model, the average price of factors (WF_f) is endogenous, whilst wage distortion factor ($\overline{WFDIST}_{fa}$) is exogenous.

Also, for each activity, the demand for disaggregated intermediate inputs is measured by the standard Leontief formulation. This is referred to as the level of aggregate intermediate input use ($QINTA_a$) times a fixed intermediate input coefficient (ica_{ca}) as expressed in the following equation.

$$QINT_{ca} = ica_{ca} \, . QINTA_a \qquad \text{(C9)}$$

Commodity Production and Allocation

$$QXAC_{ac} = \theta_{ac} \, . \, QA_a \qquad \text{(C10)}$$

In the above equation, production quantities, which are disaggregated by activity, are considered as output yields (θ_{ac}) times activity levels (QA_a). This is shown on the right hand side of the equation. On the left-hand side, the quantities are allocated between market sales and home use. This makes it possible for any commodity to be produced by one or a combination of more activities; and also, any activity able to produce one or more commodities.

Output Aggregation Function

$$QX_c = \alpha_c^{ac} \, . \, (\textstyle\sum_{a \epsilon A} \delta_{ac}^{ac} \, . QXAC_{ac}^{-p_c^{ac}})^{-\frac{1}{p_c^{ac-1}}} \qquad \text{(C11)}$$

Aggregate marketed production of any commodity is a CES aggregate of the marketed output levels of the different activities producing the commodity as indicated in the above equation. This can further be expanded to include marketed output for export and domestic use as follows.

$$QX_c = \alpha_c^t \, . \, (\textstyle\sum_r \delta_{cr}^t \, . \, QE_{cr}^{p_c^t} + [1 - \sum_r \delta_{cr}^t] \, . \, QD_{cr}^{p_c^t})^{1/p_c^t} \qquad \text{(C12)}$$

The optimal quantity of the commodity from each activity source is however indirectly related to the activity-specific price. In this case, output is *QX* which is sold at *PX*, produced with the inputs and purchased at *PXAC*.

The two equations above are the first-order conditions for maximizing profits from the sale of the aggregate output, *QX*, at price, *PX*, and subject to the aggregation function and the disaggregated commodity prices, *PXAC*. A fall in *PXAC*, of one activity relative to others would result in a shift in demand in its favour but this will not completely eliminate demand for other, higher-price sources. The degree of substitutability between different producers is dictated by the transformation of the elasticity of substitution. In terms of production economics, this is the same as a diminishing technical rate of substitution.

$$PXAC_{ac} = PX_c \, . \, QX_c \, (\textstyle\sum_{a\epsilon A'} \delta_{ac}^{ac} \, . \, QXAC_{ac}^{vaf})^{-1} . \; \delta_{ac}^{ac} \, . \, QXAC_{ac}^{-p_c^{ac}-1} \qquad \text{(C13)}$$

It is important to state that in the case where there is one producer of a given commodity, the value of the share parameter, would be 1, hence, *QXAC* = *QX* and *PXAC* = *PX*, notwithstanding the values for the elasticity and the exponent.

Output Transformation (CET) Function

$$QQ_c = \alpha_c^q . (\textstyle\sum_r \delta_{cr}^q \, . \, QM_{cr}^{-p_c^q} + \left[1 - \sum_r \delta_{cr}^q\right] . \, QD_c^{-p_c^q})^{-1/p_c^q} \qquad \text{(C14)}$$

The above equation represents output transformation function. Composite output (QQ_c) is a combination of imported output (QM) and domestically produced output (QD). Also, domestically produced output can be transformed between exports and domestic use. This follows the assumption of imperfect transformability between domestic sales and exports of marketed domestic output. Except the case of negative elasticities of substitution, the CET function applicable to commodities that are both exported and sold domestically, is identical to a CES function.

The following equation replaces the CET function for domestically produced commodities that do not have both exports and domestic sales. It allocates the entire output volume to one of the two destinations – domestic sales and exports.

$$QX_c = QD_c + \sum_r QE_{cr} \qquad \text{(C15)}$$

Composite Supply (Armington) Function

The equation below shows the Armington formulation. There is imperfect substitutability between imports and domestic output sold domestically. This is also a CES aggregation function in which the composite commodity that is supplied domestically is produced by domestic and imported commodities entering this function as inputs.

$$QQ_c = QD_c + \sum_r QM_{cr} \qquad \text{(C16)}$$

An Armington function is formulated when the domain of the function is limited to commodities that are both imported and produced domestically. In the Armington formulation, the producer produces a composite commodity using the domestically produced commodity sold to the domestic market and imports

c. Institutions Block

Factor Income and Institutional Factor Incomes

$$YF_f = \sum_{a \epsilon A} WF_f \, . \, wfdist_{fa} \, . \, QF_{fa} \qquad \text{(C17)}$$

The above equation shows the total income of each factor paid to factor owners. It is the sum of average factor prices of each factor adjusted to a fixed wage distortion factor multiplied by factor demand. The income is shared among domestic institutions in fixed shares after direct factor taxes are paid and rest of the World transfers are made. Transfers to the rest of the World are fixed in foreign currency but are transformed into local currency by multiplying by the exchange rate.

However, the equation that follows defines factor incomes paid to institutions and distributed among them at fixed shares. The institutions referenced here are the domestic institutions – households, enterprises and the government, who receive a share each of the total factor income after rest of the world transfers and factor taxes have been paid.

$$YIF_{if} = shif_{if} \,.\, YF_f \qquad \text{(C18)}$$

Income of domestic Nongovernment Institutions

$$YI_i = \sum_{f\epsilon F} YIF_{if} + \sum_{i'\epsilon INSDNG'} TRII_{ii'} + trnsfr_{igov} \,.\, cpi + trnsf_{irow} \,.\, EXR \quad \text{(C19)}$$

Domestic nongovernment institutions form a subset of the set of domestic institutions. The total income of any domestic nongovernment institution is the sum of factor incomes ($\sum_{f\epsilon F} YIF_{if}$), transfers from other domestic nongovernment institutions ($TRII_{ii'}$), transfers from the government ($trnsfr_{igov} \,.\, cpi$) indexed to the *cpi*, and transfers from the rest of the world indexed to the exchange rate (EXR).

Intra-Institutional Transfers

$$TRII_{ii'} = shii_{ii'} \,.\, \left(1 - mps_{i'}\right) .\, \left(1 - tins_{i'}\right) .\, YI_{i'} \qquad \text{(C20)}$$

In this equation, transfers between domestic nongovernment institutions ($TRII_{ii'}$) are paid as fixed shares of the total institutional incomes net of direct taxes ($\left(1 - tins_{i'}\right) .\, YI_{i'}$) and savings ($\left(1 - mps_{i'}\right).YI_{i'}$). The *mps* and *tins* are the marginal propensity to save and rate of direct taxes respectively.

Household Consumption Expenditures

$$EH_h = (1 - \sum_{i\epsilon INSDNG} shii_{ih}) \,.\, (1 - mps_h) \,.\, (1 - tins_h) \,.\, YI_h \qquad \text{(C21)}$$

For household consumption expenditure expressed in the equation above, the total value is equivalent to the income after deducting direct taxes, savings and transfers made to domestic nongovernment institutions. This is also called household disposable income which is spent on commodities.

Household Consumption Spending on Marketed Commodities and Home Commodities

In this model, it is assumed that each household maximizes a Stone Geary utility function subject to a consumption expenditure constraint in which the resulting first-order conditions are defined as linear expenditure system (LES).

$$PQ_c \,.\, QH_{ch} = PQ_c \,.\, \gamma_{ch}^m + \beta_{ch}^m \,.(EH_h - \textstyle\sum_{c' \epsilon C} PQ_{c'} \,.\, \gamma_{c'h}^m) \tag{C22}$$

In this equation, γ_{ch}^m is the minimum required quantity a consumer purchases first of one commodity. The consumer then has an option to add to the consumption from the remaining income called “supernumerary income” which is allocated to commodities in fixed shares called the marginal consumption share (or marginal budget shares). The marginal consumption share in the equation is β_{ch}^m.

It is important to note that when the minimum required quantity a consumer purchases first (β_{ch}^m), for all commodities, is zero, the household utility function changes from LES to Cob-Douglas. Therefore the LES is a generic function, hence the preference for it over other functions. In this case, the income elasticity of demand cannot be equal to 1 unless the γ_{ch}^m for all commodities is equal to 0, that is, there is no preference for any commodity even when income changes.

The household consumes composite goods and are therefore subject to composite price (PQ_c). Therefore, two equations are required to explain household consumption – consumption of marketed commodities; and consumption of home production. The demand functions can be derived by diving both sides of the two equations by the appropriate price.

Investment Demand

In the investment demand equation below, fixed investment demand is the product of the base-year quantity ($IADJ$) and an investment adjustment factor ($qinv_c$). The adjustment factor and the investment quantity are both exogenous. Inventory Investment, which is included in the model, is also exogenous.

$$QINV_c = IADJ \,.\, qinv_c \tag{C23}$$

Government Revenue

Total government revenue is the sum of revenues from taxes, factors of production, and transfers from the rest of the world. The taxes are household income taxes, import taxes and excise taxes. Import taxes are adjusted to the Exchange rate. On the transfers side, it includes, factor incomes and transfers from the rest of the world. Since Ghana exports all its oil, revenues from oil are considered part of transfers from the rest of the world.

$$YG = \sum_{i \epsilon INSDNG} tins_i \,.\, YI_i + \sum_{c \epsilon CMNR} tm_c \,.\, pwm_c \,.\, QM_c \,.\, EXR +$$

$$\sum_{c \epsilon C} tq_c \,.\, PQ_c \,.\, QQ_c + \sum_{f \epsilon F} YF_{govf} + trnsfr_{govrow} \,.\, EXR \tag{C24}$$

Government Expenditure

$$EG = \sum_{c \epsilon C} PQ_c \,.\, qg_c + \sum_{i \epsilon INSDNG} trnsfr_{igov} \,.\, cpi \tag{C25}$$

Total government spending is the sum of government consumption ($\sum_{c \epsilon C} PQ_c \,.\, qg_c$) and the sum of transfers ($\sum_{i \epsilon INSDNG} trnsfr_{igov} \,.\, cpi$) to different institutions includingnongovernmental institutions and rest of the world. Government expenditure on consumption and transfers are financed by petroleum revenues and non-oil revenues. The transfers of petroleum revenues is additional source of financing investments and socioeconomic development projects particularly through the budget; and constitute three folds – transfers to GNPC, transfers to petroleum funds and transfers to the budget. Transfers to the budget are influenced by type of fiscal rules. Thus *EG* adjusts to the amount of petroleum revenues flowing into the budget. In this model, the quantity of Government consumption is fixed, and its adjustment factor (qg_c) is exogenous. Thus, government consumption is the base year quantity times the adjustment factor.

d. System Constraint Block

There are different closures in this model. These closures are expressed for the labour markets, international trade, investments-savings and government-revenue balances.

Factor Markets

$$\sum_{a \epsilon A} QF_{fa} = QFS_f \qquad \text{(C26)}$$

The above equation shows an equilibrium condition in the factor market where total quantity of factors demanded and total quantity supplied for each factor are equal. In the basic model version, all factor demand variables are flexible but the factor supply variable is fixed. The fixing of factor supply means that all factor supplied is used.

The average factor price (WF_f) is the equilibrating variable that ensures that the market clearing condition in the factor markets are achieved. There is an indirect relationship between the factor price paid by each activity and the quantities of factor demand. This condition is based on the assumption that there is full employment in the economy. As a developing country, Ghana cannot have full-employment in the economy, but since unemployment data is not available, the assumption of full employment is adopted in this model.

Composite Commodity Markets

$$QQ_c = \sum_{a \epsilon A} QINTA_{ca} + \sum_{h \epsilon H} QH_{ch} + qg_c + qdst_c \qquad \text{(C27)}$$

This equation equates quantities supplied and demanded of the composite commodity. On the demand side, there are endogenous terms and a new exogenous term for stock change. Of the endogenous terms, QG and QINV are fixed in the basic model version. The composite commodity supply, QQ, drives demands for domestic marketed output, QD, and imports, QM. The equilibrating variables are the quantities of import supply, for the import side, and the two interrelated domestic prices, PDD and PDS, for domestic market output.

Current-Account Balance for the Rest of the World

$$\sum_{rc\epsilon CMNR} pwm_{cr} \, . \; QM_{cr} = \sum_{rc\epsilon CENR} pwe_{cr} \, . \; QE_{cr} +$$

$$\sum_{i\epsilon INSD} trnsfr_{irow} \, . \; fsav \qquad \text{(C28)}$$

The equation shows the current-account balance (expressed in foreign currency). This equates the spending by a country and its earning of foreign exchange.

In the basic model, foreign savings is fixed; whilst the market clearing variable in the current account balance is real exchange rate. Since all items with the exception of imports and exports are fixed, therefore, in effect, the trade balance is fixed. Alternatively, the foreign exchange market closure choices are also possible, such that the exchange rate can be fixed whilst foreign savings is flexible and can therefore adjust to equilibrium.

Government Balance

$$YG = EG + GSAV \qquad \text{(C29)}$$

The government balance equates current government revenue and the sum of current government expenditure and savings. This excludes investments. Savings may be negative.

Savings–Investment Balance

$$\sum_{i\epsilon INSDNG} mps_i \, . \; (1 - \overline{tins}_i) \, . \; YI_i + \; GSAV + EXR \, . \; fsav = \sum_{c\epsilon C} PQ_c \, . QINV_c$$

$$+ \sum_{c\epsilon C} PQ_c \, . qdst_c \qquad \text{(C30)}$$

The equation shows that total savings and total investment must be equal. Total savings is defined as the sum of savings from domestic nongovernment institutions, the government, and the rest of the world adjusted to local currency. Foreign savings are fixed exogenously and thereby make this model a “savings-driven” model such that total investments become the endogenous sum of the savings components. Total investment is the sum of the values of fixed investment (gross fixed capital formation) and stock changes. This is often referred to as the “neoclassical closure” in the literature.

At this point, the model is supposed to be a square in which the number of variables is equal to the number of equations. But the model as presented so far is not square. However, it satisfies Walras law because one equation which is functionally dependent on the others can be dropped. In this case, either the Savings-Investment balance or the current-account balance is commonly dropped. Once one equation is dropped, the model becomes square, and a unique solution exists. Alternatively, one variable can be added to the macroeconomic balance equations with a solution value equal to zero rather than drop one equation. For instance, it is possible to add one variable to the macroeconomic balance equations. In the GAMS version of the model, no equation is dropped. Rather, a variable called, WALRAS is added to the Savings – Investment balance to complete the model.

6.4 The Dynamic CGE Model

6.4.1 Introducing Dynamic Features in the Model

Several changes occur among some exogenous and endogenous variables over time which explains the growth process. These changes establish a counterfactual growth path for the economy. The inter-period adjustments which demonstrate dynamic features in the model are population growth, labour force growth, factor productivity and capital accumulation among others.

In the dynamic process, certain parameters are updated as the population grows. Since population growth enters the model through private consumption, the level of additional consumption demand adjusts to changes in income.

In the updating process, the level of each household's consumption adjusts to accommodate higher consumption demand as population grows. Thus, the quantity of income-independent demand increases at the rate of population growth,

In the factor market, the dynamic updating process for parameters to reflect changes in factor supply is determined by the market clearing condition in the factor market. In this model, full employment of land and labour is assumed and therefore the supply of land and labour is fixed. This implies that total land and labour supply adjust each year to reflect exogenously determined measure of land and labour force growth. In the case of total capital supply, they are endogenous in the dynamic model. It is also assumed that at any given time, total available capital is determined by the previous period's capital stock and investment expenditure, but the most important issue that remains unresolved is the determination of how the new capital from previous investments expenditure will be allocated across sectors. In this model, the new capital is allocated according to the proportion of each sectors share in total capital income and profits. The proportions are adjusted by the ratio of each sector's profit rate to the average profit rate of the economy. The capital updating process is expressed in the following equations.

$$AWF_{ft}^{a} = \sum_{a} \left[\left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) . \ WF_{ft} \ . \ wfdist_{fat} \right] \qquad \text{(C31)}$$

$$\eta_{fat}^{a} = \left(\frac{QF_{fat}}{\sum_{a'} QF_{fa't}} \right) . \ \left(\beta^{a} \ . \ \left[\frac{WF_{ft} \ . \ wfdist_{fat}}{AWF_{ft}^{a}} - 1 \right] + \ 1 \right) \qquad \text{(C32)}$$

$$\Delta K^{a}_{fat} = \eta^{a}_{fat} \,.\, \left(\frac{\sum_c PQ_{ct} \,.\, qinv_{ct}}{PK_{ft}}\right) \tag{C33}$$

$$PK_{ft} = \sum_c PQ_{ct} .\, \frac{qinv_{ct}}{\sum_{c'} qinv_{c't}} \tag{C34}$$

$$QF_{fat+1} = QF_{fat} \,.\, (1 + \frac{\Delta K^{a}_{fat}}{QF_{fat}} - v_f) \tag{C35}$$

$$QFS_{f\,1+1} = QFS_{ft} \,.\, (1 + \frac{\sum_a K_{fat}}{QFS_{ft}} - v_f) \tag{C36}$$

The first equation (equation a) shows the average economy-wide rental rate of capital (AWF^{a}_{ft}). Equation b shows that each sector's share of new capital (η^{a}_{fat}) is determined through a comparison of its rental rate to the economy-wide average rate. In this equation, the second term on the right hand side is multiplied by the existing share of capital stock to determine a sectoral distribution of new capital. Equation c shows that the quantity of new capital is determined as the value of gross fixed capital formation over the price of capital, which is then multiplied by each sector's share of new capital to determine a final quantity allocated to each sector (ΔK^{a}_{fat}). Equation d describes how the unit capital price (PK_{ft}) is calculated. In equations e and f, the new aggregate quantity of capital ($QFS_{f\,1+1}$) and the sectoral quantities of capital (QF_{fat+1}) are adjusted from their previous period levels to include new additions to the capital stock. These are adjusted to capital depreciation (v_f).

6.4.2 Model Extension: Introducing Institutional Quality

One of the major limitations of CGE models is the lack of incorporation of the quality of institutional arrangements. They fail to account for institutional settings, ethical issues and their policy concerns for societies (Söderbaum, 2000). Also, in spite of the progress in dynamic CGE models, the capital accumulation process in the models also fail to account for the impact institutional and regulatory changes on policies.; and therefore reduces the economy to an "artificial perfect macroeconomic stability" (Ackerman, 2005), which does not adequately explain the adjustment path to equilibrium.

In most econometric analyses, institutional quality has been modeled to influence the capital accumulation process in which an institutional quality proxy is related to a conventional growth model in what has become known as "institutions-augmented" growth models (see Clague et al, 1999; and Prados de la Escosura & Sanz , 2006 and 2009; Fleitas, 2011).

This study follows the idea of modeling institutional quality as part of the capital accumulation process. However, in this study, the process is modeled in a general equilibrium setting unlike the conventional "institutions-augmented" growth models that are modeled in partial equilibrium settings. In this case, investment must be defined to go beyond the accumulation of tangible assets to cover other factors such as investments in human capital and institutional processes that facilitate the efficiency of investment (Gylfason, 2001). This defines the role of the private sector and that of the government. Whereas the private sector is concerned about institutional processes that support their operations, government is concerned about processes that inhibit government and elite capture, with the view to ensuring that the growth prospects of both private and public investments are sustained in the economy.

Modeling institutional quality in a CGE model recognizes that as part of the dynamic process, the effectiveness of the adjustment path resulting from new investments can be determined by the quality of regulatory and institutional arrangements in the economy. The traditional IFPRI model has therefore been modified by the incorporation of an institutional quality index (INSTQ) denoting the quality of institutions in the economy, hence a measure of efficiency. This is particularly important for resource-rich countries that are faced with institutional challenges for the efficient management of resource revenues (Eifert et al, 2006).

To capture institutional quality index in the model, the new investments or new capital in the capital stock equation is adjusted to the index as follows:

$$QF_{fat+1} = QF_{fat} \, . \, (1 - v_f) + \Delta K^a_{fat}(1 - \frac{1}{INSTQ}) \qquad (37)$$

Where, $1 \leq \text{INSTQ} \leq 6$

Put differently, the capital stock equation is presented as:

$$QF_{fat+1} = QF_{fat} \, . \, (1 - v_f) + \Delta K^a_{fat} - \frac{\Delta K^a_{fat}}{INSTQ}$$

Where INSTQ denotes an index of institutional quality, and represented by the CPIA index.

In the CGE model, the capital accumulation process is adjusted to the quality of regulatory and institutional arrangements. This means that low level of institutional quality could be a drain on the performance of the economy by limiting the efficiency of investments including investments from petroleum revenues. If the institutional quality index is low, it implies that institutions are weak, and the effect on fiscal rules will translate into low capital accumulation with adverse results on development impacts. On the other hand, if the index is high, it denotes strong institution, with positive implications for the development impacts of fiscal rules.

The capital equation has a dynamic structure in which every solution runs tracks the economy over the study period (2010 to 2030) covering the production profile of the Jubilee field and other fields that are coming on stream. Capital accumulation is influenced by savings (particularly for private capital accumulation) and government decisions on allocation of public funds.

Investment and capital accumulation for that matter is also influenced by foreign inflow of capital or foreign savings, in which new investments in the oil and gas sector as well as new petroleum revenues become important variables for the simulations. Distribution of increased capital across sectors is determined relatively by the returns to capital, which are endogenous in a general equilibrium model. The dynamism is based on the assumption that future capital accumulation is a function of the efficiency of current investments. This makes the quality of institutions very relevant as it demonstrates the efficiency of investments (Collier and Venables, 2008).

The CPIA Index measures how enabling the policy and institutional framework is in fostering poverty reduction, sustainable growth, and the effective use of development assistance. It therefore measures the standards for resource allocation to IDA countries. It is also used to measure a country's fiscal sustainability analysis, and therefore determines 'the grant-to-loan ratio in each country's allocation of assistance' (Alexander, 2010).

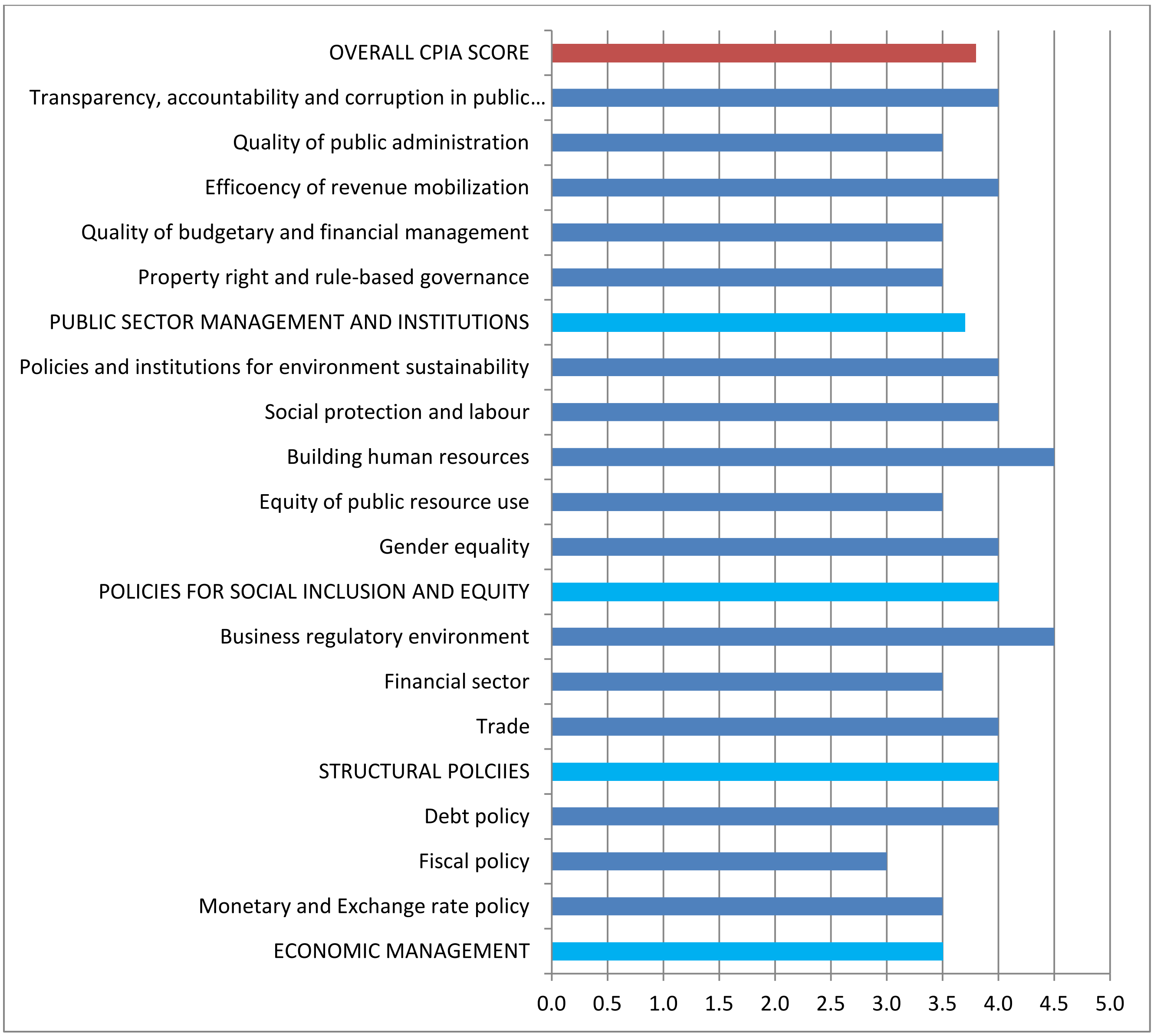
The CPIA which is published by the World Bank has four (4) clusters presented in sixteen (16) dimensions as follows:

Table 6.1: Clusters of CPIA

CLUSTER A: ECONOMIC MANAGEMENT
Monetary and Exchange rate policy
Fiscal policy
Debt policy
CLUSTER B: STRUCTURAL POLCIIES
Trade
Financial sector
Business regulatory environment
CLUSTER C: POLICIES FOR SOCIAL INCLUSION AND EQUITY
Gender equality
Equity of public resource use
Building human resources
Social protection and labour
Policies and institutions for environment sustainability
CLUSTER D: PUBLIC SECTOR MANAGEMENT AND INSTITUTIONS
Property right and rule-based governance
Quality of budgetary and financial management
Efficiency of revenue mobilization
Quality of public administration
Transparency, accountability and corruption in public sector

Scoring for the CPIA follows a pattern from "1" = Very weak for 2 years or more, "2" = weak, "3" = moderately weak, "4" = moderately strong, "5" = strong and "6" =very strong for 3 years or more. Thus, countries with higher scores are said to have strong policy and institutional arrangements for managing public resources. The following figure 6-1 presents Ghana's 2012 CPIA performance:

Figure 6-1: Ghana CPIA Performance in 2012



Source: World Bank, CPIA Africa, Assessing Africa's Policies and Institutions (June, 2013)

The institutional weaknesses in the country's public administration, budgetary and financial management; and fiscal policy constitute serious barriers that could prevent the transformation of petroleum revenues into positive development outcomes in the economy.

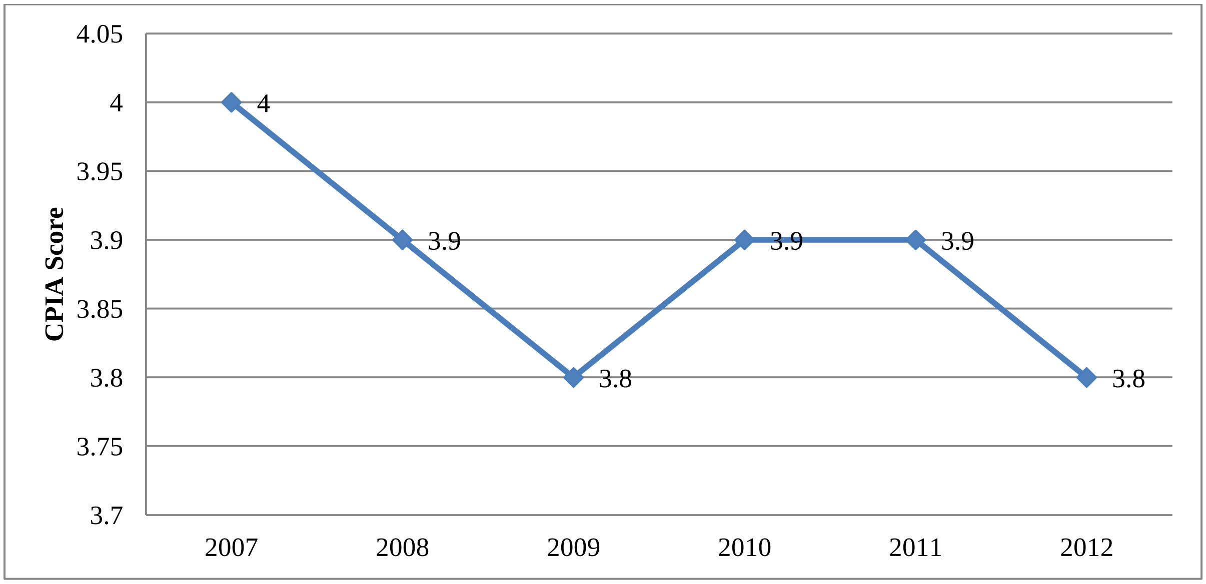
From Figure 6-1, Ghana performed poorly in Economic Management (3.5) comprising Fiscal Policy, Monetary and Exchange rate Policy, and Debt policy and Public Sector Management and Institutions (3.7) consisting of Transparency and Accountability and Corruption in Public Sector, Quality of public administration, Efficiency of revenue mobilization, Quality of budgetary and financial management; and Property right and rule-based governance. Thus, the country is moderately weak in these very important clusters which provide the enabling environment for efficiently managing new revenues coming from oil.

However, the country's performance in Structural Policies and Policies for Social Inclusion and Equity (4.0) was moderately strong. These sectors are nevertheless likely to be weakened if the institutional management arrangements in the country remain weak.

At the micro-level, Ghana's worse performance is in fiscal policy (3.0) on account of deteriorating fiscal balance arising from lower than expected revenues and higher current expenditure. Ghana's performance in the areas of Quality of public administration, Quality of budgetary and financial management; and Property rights, rule-based governance, exchange rate management and financial sector management are moderately weak (3.5).

It is also important to state that although Ghana scored high in some cluster areas than others, overall, the country's performance from 2007 to 2012 shows a declining trend as presented below in Figure 6-2. For instance, Ghana's CPIA declined from an average score of 4 in 2007 to 3.8 in 2012. Ghana therefore needs to improve on its policy and institutional reforms to provide the environment for efficient resource management including petroleum resources.

Figure 6-2: Ghana's CPIA Trend over time (2007-2012)



Source: World Bank, CPIA Africa, Assessing Africa's Policies and Institutions (June, 2013)

6.5 The Ghana Social Accounting Matrix (SAM)

The model is calibrated to the updated Ghana 2007 Social Accounting Matrix (SAM) used Briesinger et al, (2011). Data on national accounts was provided by Ghana Statistical Services (GSS), and other data such as balance of payments provided by the Bank of Ghana, and government budget data provided by the Ministry of Finance. The updated Ghana SAM gives information covering demand and production structures of 70 detailed sectors, comprising of 27 agricultural subsectors, 33 industrial subsectors, and 10 service subsectors. This makes it possible to examine sector and sub-sector specific effects on the economy. The sectors and commodities used in the CGE model are presented in the following Table.

Table 6-2: Sectors/Commodities in Ghana CGE Model

Agriculture	**Industry**	**Industry**	**Services**
Cereal crops	**Mining**	Electrical machinery	**Private**
Maize, rice, sorghum/millet	Gold	Televisions	Trade services
Other cereals	Other mining	Medical appliances	Export services
Root crops	**Food processing**	Vehicles	Transport services
Cassava, yams, cocoyam	Formal food processing	Other technical equipment	Communication
Other staple crops	Vehicle parts	Other equipment manufacturing	Banking and business
Cowpeas, soybeans	Informal food processing	**Other industry**	Real estate
Groundnuts	Cocoa processing	Construction	**Public and community**
Fruits (domestic)	Sugar processing	Water	Community, other services
Vegetables (domestic)	Dairy product processing	Electricity	Public administration
Plantains, other crops	Meat and fish processing		Education
Export crops	**Other manufacturing**		Health
Palm oil, other nuts	Textiles		
Other nuts, fruits (export)	Clothing		
Vegetables (export)	Leather and footwear		
Cocoa beans	Wood products		
Industrial crops	Paper, publishing and printing		
Livestock	Crude and other oils		
Chickens (broilers)	Petroleum		
Eggs and layers	Diesel fuel		
Beef	Other fuels		
Sheep and goat meat	Fertilizers		
Other meats	Chemicals		
Forestry	Rubber products		
Fishery	Other nonmetal products		
	Machinery		

The dynamic CGE model used in this study is an economy-wide, multi-sectoral model and solves for equilibrium quantities and prices of economic variables simultaneously and endogenously. For supply and demand decisions, behaviour is captured by nonlinear, first-order optimality conditions. This implies that supply and demand decisions are driven by the maximization of profits and utility, respectively. On the supply side, the model defines specific production functions for each economic activity. The activities include agriculture and non-agriculture which also covers industry and services. Profits are maximized subject to a production technology. In this model, we assume constant returns to scale and two service sub-sectors (private and public).

The Ghana SAM is a data framework which contains information about national income and product accounts and the input-output table, including the monetary flows between institutions. In this data framework, total income equates total expenditures for each of the component accounts. The reconciliation of incomes and expenditures follows a double entry system in which data on rows are equal to data on columns. The reliability of the various data sources is first assessed on the basis of observed inequalities between row and column accounts. The SAM is then balanced using cross-entropy econometrics. A “macro” version of the SAM is first prepared before it is disaggregated across sectors, factors and households to derive a more detailed ‘micro’ version (See Ghana Macro SAM below).

Table 6-3: Ghana Macro SAM

Sum of Value	*Column*														
Row	Act	Com	Trc	Lab	Cap	land	hhd	Gov	dtax	Stax	Mtax	Etax	s-i	row	Grand Total
Act		170,770													170,770
Com	82,176		2,836				85,093	15,473					28,207	35,097	248,884
Trc		2,836													2,836
Lab	48,600														48,600
Cap	22,318														22,318
Land	18,071														18,071
Hhd				48,600	22,318	18,071		3,701						2,007	94,697
Gov									6,235	10,304	3,524	1,089		5,714	26,866
Dtax							6,235								6,235
Stax		10,304													10,304
Mtax		3,524													3,524
Etax	-395	1,484													1,089
s-i							3,369	6,776						18,062	28,207
Row		59,966						915							60,881
Grand Total	170,770	248,884	2,836	48,600	22,318	18,071	94,697	26,866	6,235	10,304	3,524	1,089	28,207	60,881	743,280

Source: IFPRI (2009)

The SAM distinguishes between ‘activities’ (the entities that carry out production) and “commodities” (representing markets for goods and non-factor services). SAM flows are valued at producers’ prices in the activity accounts and at market prices (including indirect commodity taxes and transactions costs) in the commodity accounts. The commodities are activity outputs, either exported or sold domestically, and imports. In the activity columns, payments are made to commodities (intermediate demand), and factors of production (value-added comprising of operating surplus and compensation of employees). In the commodity columns, payments are made to domestic activities, the rest of the world, and various tax accounts (for domestic and import taxes). This treatment provides the data needed to model imports as perfect or imperfect substitutes vis-à-vis domestic production.

a. Government Income and Payments

The government is disaggregated into a core government account and different tax collection accounts, one for each tax type. This disaggregation is necessary since otherwise the economic interpretation of some payments is often ambiguous. In the SAM, direct payments between the government and other domestic institutions are reserved for transfers. Finally, payments from the government to factors (for the labour services provided by public sector employees) are captured in the government services activity. Government consumption demand is a purchase of the output from the government services activity, which in turn, pays labour.

b. Domestic Non-Government Institutions

The domestic non-government institutions consist of households and enterprises. The enterprises earn factor incomes (a reflection of ownership of capital and/or land) and may also receive transfers from other institutions. Their incomes are used for corporate taxes, enterprise savings, and transfers to other institutions. Unlike households, enterprises do not demand commodities. It is possible to disaggregate the enterprise sector in a manner that captures differences across enterprises in terms of tax rates, savings rates, and the shares of retained earnings that are received by different household types.

c. Home and Final Household Consumption

The SAM distinguishes between home (own) consumption of activities and marketed consumption of commodities by households. Home consumption, which appears in the SAM as payments from household accounts to activity accounts, is valued at producer prices, i.e., without marketing margins and sales taxes that may be levied on marketed commodities. Final household consumption of marketed commodities appears as payments from household accounts to commodity accounts, valued at consumer prices including marketing margins and taxes.

6.6. Calibrations of the Model - Elasticities and Parameters

A dynamic CGE model requires several elasticities in addition to the SAM being the major source of data used to calibrate some parameters. The most important elasticities are:

a. The elasticity of substitution between primary inputs in the value-added production function,

b. The elasticity of transformation between domestically produced and consumed goods and exported or imported goods,

c. The income elasticity in the demand functions.

Some of the elasticities are calibrated from the SAM, but others are borrowed from the literature. The elasticities that are calibrated directly from the SAM as well as those borrowed from literature include:

i. The parameters or coefficients in the production functions of the model are derived from the Ghana SAM.

ii. In the case of intermediate inputs in the production function, a set of fixed input–output coefficients are derived from the Ghana SAM based on the assumption of Leontief technology.

iii. Marginal budget shares which are the parameters used in the demand system, were derived from the Ghana SAM, given income elasticities of demand.

iv. The income elasticities of demand were estimated by Briesinger et al, (2011) from a semi-log inverse function suggested by King and Byerlee (1978) and based on the data of Ghana Living Standard Survey 5 (2005–06) (GSS 2007).

v. CES elasticity in the production function is drawn from the CGE literature on other African countries.

vi. A CET function applied to commodities sold both domestically and abroad, whilst a CES (or Armington) function applied to commodities that are produced domestically and from abroad. The elasticities of these functions were adopted from Hertel et al, (2007).

The following Table shows the Trade and production elasticities adopted for the study.

Table 6-4: Elasticities

Trade Elasticities (TRADELAS)			**Production Elasticities (PRODELAS)**		
Subsectors	***Armington***	***Transformation***	**Subsectors**	***Factor substitution***	
	SIGMAQ	**SIGMAT**		**PRODELAS**	**PRODELAS2**
Cocoa Beans	6.5	4.0	All sectors/subsectors	0.75	1.20
Forestry	5.0	4.0			
Fishing	2.5	4.0			
Mining	6.0	4.0			
Petroleum	10.4	4.0			
Construction	6.0	4.0			
Water	6.0	4.0			
Electricity	6.0	4.0			
Trade	4.0	4.0			
Communication	4.0	4.0			
administration	4.0	4.0			
Education	4.0	4.0			
Health	4.0	4.0			

Source: Hertel et al, (2007)

6.7 Conclusions

The Ghana CGE model illustrates the economy-wide effect of policy shocks. In this study, the impacts of fiscal rules for spending petroleum revenues on the economy have been examined. The fiscal rules include the permanent income, bird-in-hand and Ghana's fiscal rule for allocating petroleum revenues to the budget. However, since fiscal rules by themselves do not guarantee the efficiency of public spending, the model structure was modified to incorporate an index of institutional quality to measure fiscal efficiency. The results and analysis of the policy simulations are presented in the next chapter.

CHAPTER SEVEN

FISCAL RULES AND ECONOMIC DEVELOPMENT

7.1 Introduction

This section presents analysis of the simulation results with appropriate illustrations. The main objective of the CGE model is to examine the development impacts of alternative fiscal rules. To meet this objective, seven policy simulations were conducted in a recursive dynamic model. The simulations were based on fiscal benchmarks computed from the permanent income, bird-in-hand and Ghana's fiscal rules. The simulations reflected two of the research questions which sought to examine (i) the development impacts of the permanent income rule, the bird-in-hand rule and Ghana's fiscal rule for determining the optimal limits of Government spending of petroleum revenues; and (ii) the development impacts of the efficiency of the alternative fiscal rules. The efficiency of fiscal rules was measured by the introduction into the Ghana CGE model an index representing the quality of institutions in Ghana adopted from the Country Policy and Institutional Assessment (CPIA) Index of the World Bank.

The results from the simulations show that the permanent income rule has greater impact on economic development than the alternative bird-in-hand and Ghana's fiscal rules. These impacts were assessed on the macroeconomic environment, household expenditure, factor incomes and productive sector performance. A summary of simulation results on the macroeconomic effects of fiscal rules are presented in the following Table 7-1.

Table 7-1: Macroeconomic Effects of Fiscal rules, 2030

Variables	Initial Value	Base run	Permanent Income (PI)	Bird in hand (BIH)	Ghana rule (GH)
GDP (Value-added)	103902.712	152625	10.140%	0.104%	1.21%
Absorption	128818.204	224779	10.140%	0.104%	1.21%
Private Consumption	85090.853	147507	10.920%	0.112%	1.31%
Fixed Investment	28206.913	51536.4	14.820%	0.152%	1.77%
Exports	32112.462	58653.5	17.940%	0.184%	2.15%
Imports	-57027.954	-98508	10.140%	0.104%	1.21%

Source: Author based on Ghana's Computable General Equilibrium Model

The long-term macroeconomic environment improves with increased government spending based on the permanent income rule. This is followed by Ghana's fiscal rule and then the bird in hand rule. For instance, the long-term growth of the economy under the permanent income rule is expected to be 10.1% relative to the bird-in-hand rule (0.1%) and Ghana's fiscal rule (1.2%). The permanent income rule appears consistent with Ghana's growth trajectory considering that the economy grew at 13% in 2011. However, if this growth is to be sustained as it appears under the permanent income rule, then the rule will likely overheat the economy. The economy's long-term growth under the current fiscal model of Ghana will not be consistent with expectations for maximizing welfare. Thus, Ghana's rule is not only fiscally un-sustainable but also fiscally non-optimal.

In the analysis of fiscal sustainability, the bird in hand rule was the most fiscally sustainable but its impact on the development of the macroeconomic environment is relatively insignificant.

Thus what it means is that with temporary petroleum revenues, the Government should not only be concerned about fiscal sustainability but also the impacts the resources could make on the economy when invested efficiently.

It is also important to note that the long-term growth in GDP will be fuelled by growth in private consumption (10.9%), fixed investments (14.8%) and exports (17.9%). Imports are also expected to grow but this is unlikely to have decelerating effect on long-term growth as terms of trade are expected to improve, relying on strong export growth. The growth in exports will be realized based on increasing private consumption as private sector investments have overtaken government investments. It has been estimated that Government controls about 43 of investment spending whilst private consumption accounts for 53.5% and the rest, 3.1%, comes from other non-government-related foreign inflows such as Foreign Direct Investments (Briesinger et al, 2011).

Private consumption could also increase if government increases its spending through the permanent income model and substitute domestic borrowing with petroleum revenues. This will release loanable funds to the private sector and thereby increase private consumption. However, as it is now, Government is unlikely to substitute petroleum revenues for domestic borrowing under its current fiscal rule which allocates insignificant proportions of petroleum revenues to the budget unless during the peak oil production period. Thus, under Ghana’s fiscal rule, the only condition that could increase allocations of petroleum revenues to the budget is through substantial increase in oil production which is unlikely without new discoveries of oil and gas resources with proven commercial viability.

Also, the simulation results show that Ghana could successfully go through structural transformation if it adopts the right fiscal policy which is export enhancing. Countries that have succeeded this way, have been associated with high exports, which in most cases exceeded overall economic growth such as experienced in Brazil and Malaysia in the 1960s and India and Vietnam in the 1990s.

On the development impacts of the fiscal efficiency of fiscal rules, the results show that the quality of institutions in a country enhances the benefits that can be derived from the management of petroleum revenues. In the following Table 7-2, Ghana's fiscal rule could inject increased development impacts based on efficiency gains from the institutional arrangement for managing petroleum revenues. With a CPIA of 6 indicating very strong institutions, the efficiency gains on Government expenditure based on Ghana's fiscal rule are higher for all the macroeconomic variables compared to a CPIA of 3 indicating moderately weak institutions. For instance, GDP in value added terms grows by an additional 1.19% with strong institutions as against 0.03% with weak institutions. It can be deduced that with a CPIA of 6, GDP growth almost doubled. This trend is the same for fixed investments and exports.

Table 7-2: Impact of Efficiency of fiscal rules on the Economy, 2030

Variables	**Base (Bil ¢)**	**GH rule**	**Efficiency Gains**	
			CPIA3	**CPIA6**
Absorption	103902.712	1.21%	0.024%	0.96%
Private Consumption	128818.204	1.21%	0.025%	0.997%
Fixed Investment	85090.853	1.31%	0.035%	1.36%
Exports	28206.913	1.77%	0.035%	1.56%
Imports	32112.462	2.15%	0.02%	0.88%
GDP (Value-added)	-57027.954	1.21%	0.03%	1.19%

Source: Author based on Ghana's Computable General Equilibrium Model

It is therefore important to state that Ghana could achieve higher development impacts from its petroleum revenues if efforts are made to build strong institutional frameworks within which petroleum revenues are managed. This implies building the independence of regulatory institutions such as revenue collecting agencies, development planning agencies, environmental protection agencies; and accountability agencies such as Parliament, the Judiciary and other quasi-judicial bodies. The analysis of the simulation results on other economic variables are presented in the following sections.

7.2 Analysis of Simulation Results

The simulations that were conducted are outlined as follows:

Scenario 1: Development impacts of fiscal rules

SIM1: Increase Government current expenditure by 11.7% based on the permanent income rule

SIM2: Increase Government current expenditure by 0.12% based on the bird-in-hand rule

SIM3: Increase Government current expenditure by 1.4% based on Ghana's fiscal rule

Scenario 2: Development impacts of the efficiency of fiscal rules

SIM4: Increase Government current expenditure by 1.4% with an institutional quality index of 3

SIM5: Increase Government current expenditure by 1.4% with an institutional quality index of 6

SIM6: Increase Government current expenditure by 11.7% with an institutional quality index of 3

SIM7: Increase Government current expenditure by 11.7% with an institutional quality index of 6

The results from the above simulations are analyzed in the following sections:

7.2.1 Comparison of the Impacts of the permanent income, the bird-in-hand and Ghana's fiscal rules on Factor Markets

Factor inputs are required at both the primary and intermediate levels to make production of commodities possible. In return, factor inputs are paid for their contribution. Capital receives rent whilst labour receives various forms of wages. In this study, it is assumed that capital is fixed but labour is mobile across sectors and is disaggregated between sectors. Land characteristics differ by region and attract different prices. For instance, Southern land is much more expensive than Northern land.

The simulation results show that the permanent income rule offers significant earning opportunities for all factor inputs with a growth in income for self-employed agricultural labour of 0.4% as against 0.05% and 0.004% for Ghana's fiscal rule and the bird-in-hand rule respectively . This is largely attributed to the higher proportion of Government spending associated with the permanent income rule in the early years of oil production. However, the distribution of income varied by factor inputs. Of all the three main factor inputs analyzed, labour inputs make the most gains although marginally. For instance, unskilled non-agricultural labour makes the most improvement in income levels (0.7%), followed by skilled non-agricultural labour (0.44%) and then skilled agricultural labour (0.41%).

Table 7-3: Effects of Alternative Fiscal rule on Factor Incomes

Factor Inputs	Base	PI	GH	BIH
Land (North)	1.7	0.14	0.012	0.001
Land (South)	1.9	0.27	0.033	0.003
Land (Forest)	1.7	-0.19	-0.02	-0.002
Land (Coast)	2.05	0.12	0.014	0.001
Unskilled Labour (non-agric)	2.6	0.7	0.08	0.007
Skilled labour (non-agric)	2.3	0.44	0.052	0.004
Self-employed labour (agric)	2.1	0.41	0.05	0.004
Capital	1.7	0.1	0.01	0.001

Source: Author based on Ghana's Computable General Equilibrium Model

Theoretically, there are two main reasons for the growth of incomes of labour inputs. First, an increase in government spending increases aggregate demand in the economy which requires the supply side to respond. The need for supply to respond to the growing demand in turn increases the demand for labour but since supply is assumed to be constant in the simulation model, higher demand for labour translates into higher factor prices and higher income levels for that matter. Second, higher government spending also increases private investments as a result of Government transfers to private institutions including debt repayments. This leads to expansion in the economy and more jobs are created especially for skilled manufacturing labour. Factor inputs such as skilled non-agricultural labour become more competitive, hence an increase in factor prices in the non-agriculture labour market.

In addition, most of the public investments in Ghana are concentrated in the capital, Accra, and dominated by non-agricultural labour seeking jobs in the manufacturing and services sectors. These include mechanics that are hired in light industrial areas and unskilled casual workers working in the roads and construction industries. They are therefore part of the factor inputs to benefit from the distributive effects of government spending.

Also, when government investment priorities are more focused on road infrastructure where most of the labour inputs are temporary and casual, the beneficiaries are almost unskilled receiving daily wages. Since 2011, the Government prioritized road infrastructure, agricultural modernization, capacity building and amortization of loans for oil and gas infrastructure for the spending of petroleum revenues. Thus, with a higher allocation of revenues as it is under the permanent income simulations, the impact on the incomes of unskilled non-agricultural labour will be greater.

In the case of self-employed agricultural labour, the growth in income can be attributed to government social programmes including fertilizer subsidies and other government transfers. This confirms the finding by Keuning and Thorbecke (1989) in Cameroon who state that government household transfers have the greatest direct impact on incomes of agricultural employees.

In the case of capital earning, the rental gain is marginal (0.1%) because most of the capital employed are in the capital intensive industries such as oil, gas, and mining, where earnings are very high but are more stable and are not likely to benefit much from increased government spending. Moreover, most of the capital intensive industries are controlled by the private sector; and the spillover from government spending may be insignificant.

Also, land owners make marginal gains in income differentiated by the location of the land. For instance, with permanent income rule, southern land owners make the highest gain in income among the land input category (0.27%) against Northern land (0.14%) and Coastal land (0.12%), because most investments that require land are concentrated in the south. Southern lands are very expensive, and the growth of government spending will likely increase the value of land arising from the inflationary effects and the high demand for land for new investments. Earnings for forest land falls marginally (-0.24%) due to low demand for land for public investments.

7.2.2 Comparison of the Impacts of the permanent income, the bird-in-hand and Ghana's fiscal rules on Household Expenditure

In this analysis, households are disaggregated into Accra (the capital city), other urban areas in the South, North and Coastal areas; and as well as rural parts of Ghana. The disaggregation has become relevant because there are differential effects of public spending on different categories of households. Also, household sizes differ by location. For instance, household sizes in Northern Ghana are larger (at an average of 8) than Southern sector households (an average of 5). Income levels also differ, with households in the urban areas enjoying higher income levels. Differences across income groups affect their marginal propensities to save and the impacts of income elasticity of aggregate demand due to increased income levels from government transfers to households, which also depends on the distribution of the income across income groups (Shapiro and Slemrod 2003).

The expenditure of households is influenced by their marginal propensity to spend which is higher for low income households relative to the growth in their earnings as against high income households. Put differently, Friedman (1957) observes that people with high income will tend to save more to compensate for lower future income, and people with low income will tend to save less in anticipation of higher future income. In spite of their higher marginal propensity to spend, lower income household's expenditure size is lower accounting for the slow growth in their consumption.

Table 7-4: Effect of Ghana's Fiscal rule on Household Consumption, 2030 (% change)

Household	**Base run (Bil¢)**	**BIH**	**PI**	**GH**
URBAN				
Accra	22073.8	0.19%	18.7%	2.2%
Coast	7553.88	0.15%	14.8%	1.8%
Forest	12006.1	0.15%	14.8%	1.8%
South	11772.4	0.16%	15.6%	1.9%
North	2670.94	0.18%	17.2%	2.1%
RURAL				
Forest	6910.22	0.13%	12.5%	1.5%
South	16245.2	-0.08%	-7.8%	-0.9%
North	17673	0.06%	5.5%	0.7%
Accra	10088.7	0.08%	7.8%	0.9%

Source: Author based on Ghana's Computable General Equilibrium Model

Table 7-4 above illustrates the impact of increasing public spending on household purchasing power based on alternative fiscal rules. Purchasing power is the real income of households which is determined by subtracting income taxes from household earnings as providers of factor inputs in the production process.

Households form habits over certain narrowly defined consumption of goods (like cars, clothing etc.) which gives a demand function with two components - a price-elastic component depending on aggregate consumption demand; and a perfectly price-inelastic component (Grohe and Uribe, 2006). Thus, a rise in aggregate demand through public expenditure raises the share of the price-elastic component, which induces firms to reduce their markup price over marginal cost. This then raises labour demand and since labour supply is assumed constant in the model, the result is an increase in real wages. Thus, increased public expenditure increases the purchasing power of certain categories of households (urban households) which could therefore lead to a rise in consumption.

The increase in household consumption expenditure is based on the fact that public expenditure increases household incomes much more than private expenditure because of the social considerations that guide public spending such as cash transfers and the greater labour intensity of social programmes. Increased household incomes and consumption in turn increases the size of government income through taxes paid to the government. This confirms the general view that government expenditure has the greatest potential to generate government revenue.

This point of view has often been exploited by proponents of direct cash transfer as the appropriate model for distributing petroleum revenues. They argue that direct cash transfer as opposed to investment of petroleum revenues increases the purchasing power of households, increases household consumption and government income through taxes. They also argue that such transfers ensure equitable distribution of resource wealth and reduce inequality with long-term implications for increasing household welfare (Goldsmith, 2002, 2010).

Transfers also help poor workers to invest in more productive job searches by moving out of an extended household and migrating in pursuit of better jobs elsewhere (Ardington, Case and Hosegood, 2008); enables workers to make investment in skills, or even set up their own small businesses (De Mel, McKenzie and Woodruff, 2008; Sadoulet, de Janvry and Davis, 2001); and help the poorest in the society to forego the worst forms of labour that they would otherwise be compelled to do out of desperation (Wittenberg, 2002). These instances cited here show that direct cash transfers could contribute to productivity, labour input earnings, and increase government tax income.

However, this does not apply to all cases particularly in oil producing countries that do not depend on tax revenues. Further, direct transfers might not necessarily increase government income if households engage in unproductive consumption, and could decrease labour participation (Bertrand, Miller and Mullainathan, 2003); and lead to negative effects on the future consumption of households.

The simulation results again show that the permanent income rule has higher impact on household expenditure, followed by Ghana’s fiscal rule and the bird in hand rule. For instance, an adoption of the permanent income rule can in the long-term increase the expenditure of both urban and rural households relative to the alternative rules. However, under all the fiscal rules, urban household expenditure is relatively higher than rural household expenditure for all categories of households. This could be explained by different factors.

First, the bulk of Ghana’s poor are in the rural areas of the country whose earnings are much lower, mostly subsistence self-employed farmers. Second, productivity levels in the rural areas are much lower due to low human capital accumulation, which makes labour non-competitive; hence rural labour does not attract higher and competitive wages.

In Ghana, farm labour is abundant and less expensive in Rural North where farming is seasonal, relative to Rural Forest where farming is a year round activity. This accounts for the differential long-term growth in the expenditure of households from these areas (12.5%) in Rural Forest as against 5.5% in Rural North.

The results also show that although permanent income based spending can increase urban household expenditure by all categories of households, there will continue to be some disparities between urban household groups. Accra Urban household expenditure grows the most at 18.7% followed by Urban North (17.2%), Urban South (15.6%) and Urban Coast and Forest both at 14.8%.

The most significant growth in household expenditure occurs in Urban North. This may be premised on the fact that government interventions on poverty reduction will be given a boost from increased public transfers. So far, some of the interventions which support the growth of the northern economy are the Savannah Accelerated Development Programme (SADA) and other transfers including fertilizer subsidies partly financed from petroleum revenues, building of school blocks to replace ‘schools under trees”, among others. SADA is an important intervention aimed at narrowing the development gap between Northern and Southern Ghana. It has a Board, and management team headed by a Chief Executive Officer. The programme is created by law under Act 805 of 2011.

These interventions have created opportunities for the emergence of a middle income group resulting from increased business opportunities, Government Contracts, the opening of branches of financial institutions and factories. An increase in public investment in the North therefore accounts for the long term growth in the expenditure of Urban North Households, with greater potential for bridging the development gap between the Northern and Southern parts of Ghana.

7.2.3 Comparison of the Impacts of the permanent income, the bird-in-hand and Ghana's fiscal rules on Productive Sectors

Increased public spending affects the productive sectors of the economy differently. Public spending based on alternative fiscal rules also has different effects. As already stated earlier, the economy's long-term growth varies by fiscal rule – permanent income (10.1%), bird-in-hand (0.1%) and Ghana's fiscal rule (1.2%). Therefore under the permanent income rule, the economy is expected to consolidate Ghana's middle income status. The long-term growth is fueled by the growth of industry particularly electricity (37%), petroleum (25%) and construction (16%) subsectors. This is followed by the services sector led by trade (38%) and communications (30%).

The agriculture sector contributes the least with cocoa leading the agricultural growth with 7%. The trend in this analysis shows that Ghana can see structural transformation over the long-term horizon as industry growth overtakes both services and agriculture. The summary of the impacts of all the fiscal rules on the productive sectors are presented in the following Table 7-5.

Table 7-5: Effects of Fiscal rules on productive Sectors, 2030

Sectors	Official 2010	Base run (Bil¢)	BIH	PI	GH
Cocoa Beans	4.6%	2517.798	0.31%	6.8%	0.59%
Forestry	3.8%	59.63	0.63%	5.34%	0.53%
Fisheries	5.0%	1695.7	0.17%	6.38%	0.51%
Mining	11.2%	5330.61	0.04%	9.13%	0.96%
Petroleum		402.582	0.26%	25.43%	3.04%
Construction	7.9%	12240.6	0.17%	16.38%	1.96%
Water	1.8%	207.219	0.40%	13.31%	1.270%
Electricity	16.7%	3404.25	0.89%	36.50%	4.35%
Trade	9.1%	5949.24	0.39%	37.83%	4.53%
Communications	19.6%	2199.23	0.32%	30.07%	3.71%
Public Admin	7.6%	14682.7	0.00%	6.23%	0.63%
Education	7.1%	3115.33	0.00%	5.31%	0.04%
Health	8.2%	911.317	0.03%	7.12%	0.87%

Source: Author based on Ghana's Computable General Equilibrium Model

7.2.3.1 Agricultural Sector Growth

Increased government expenditure based on the permanent income rule has positive impact on the agriculture sector contributing to the growth of the cocoa sub-sector at 7%, fisheries at 6% and forestry at 5%. Cocoa subsector continues to contribute significantly to the economy as it has done in the last two decades.

Briesinger et al, (2011) observes that Cocoa is Ghana's most important traditional export crop which has been contributing almost three times more than expected from its size of the economy. The cocoa sub-sector has also been the main driver behind land expansion in Ghana accounting for 60% of total cultivated land increase in 12 years.

As a result of its contributions to the economy, Government has supported the subsector with policy and resources including publicly funded mass spraying of cocoa farmers, cultivation of improved seeds and payment of bonuses to cocoa farmers when the producer price of cocoa increases. However, the long term growth in cocoa is higher than its 2010 level of 5% indicating that increased spending from petroleum revenues can have great impact on the economy.

It is also important to note that the agricultural sector needs to be diversified away from over dependence on cocoa and efforts need to be made to invest in other crops. The Government has already prioritized other agricultural programmers' for the spending of petroleum revenues focusing on what could accelerate poverty reduction. Therefore in 2011 and 2012, the Government allocated GHS13.1 million and GHS72.4 million from petroleum revenues respectively to agricultural programmes covering:

a. Fertilizer Subsidy
b. Agricultural Mechanization
c. Tsetse Project
d. Youth in Agriculture Project
e. Counterpart Funds for Afram Plains Area Development Project
f. Inland Valley Rice Development Project
g. Root Tuber Improvement Programme
h. Northern Rural Growth Programme

These programmes are intended to reduce poverty among rural populations because of the redistributive effect of agricultural investments.

Also, even though cocoa exports are likely to grow, increased processing of cocoa will likely increase the value of raw cocoa beans. In the past decade, significant efforts have been made at increasing cocoa processing capacity and the capacity of the Cocoa Processing Company and the West African Mills Company, have been improved whilst new capacities have been either set up or planned by the two major international companies (Osei 2008).

Table 7-6: Impact of fiscal rules on agriculture, 2030

Sectors	Official 2010	Base run (Bil¢)	BIH	PI	GH
Cocoa Beans	4.60%	2517.8	0.31%	6.80%	0.59%
Forestry	3.80%	59.63	0.63%	5.34%	0.53%
Fisheries	5.00%	1695.7	0.17%	6.38%	0.56%

Source: Author based on Ghana's Computable General Equilibrium Model

The forestry subsector also shows strong growth in the long-term over its current levels, growing at 5% by 2030. Ghana's forest cover has been depleting over the years as a result of deforestation and global climate change causing a drastic loss of biodiversity (Dixon et al, 1996). It has been estimated that almost 14% of the total permanent forest reserves in the country have no adequate forest cover with the most affected being the North-West and South-East sub-type of forest zones (Tabi, 2001). There is excessive illegal and legal logging, bushfires, surface mining and weak implementation of forest regulations. To achieve this expected growth in the long-term, Government expenditure must target increasing Ghana's forest cover. Several efforts including the National Plantation Programme must be reactivated to make the forestry sub-sector contribute to the growth of the economy.

On the part of fisheries, the long-term growth is not much different from the level in 2010. This requires extra attention through government intervention. It is expected that oil and gas activity could affect the fisheries subsector more which must be evaluated to ensure that the economy is not negatively affected. This is particularly serious because a significant proportion of the population in the coastal areas that border Ghana's offshore oil operations depend on fishing for their livelihoods.

7.2.3.2 Industry Sector Growth

The industrial sector growth is led by electricity, petroleum and construction sub-sectors. On the relative effects of the fiscal rules, the simulation results show that the permanent income based government spending provides greater impact on industrial growth largely on account of the growth potential of industrial investments. Particularly, investments in infrastructure which is required to support industrial activity requires substantial financing which the permanent income rule offers relative to the bird-in-hand and Ghana's fiscal rules.

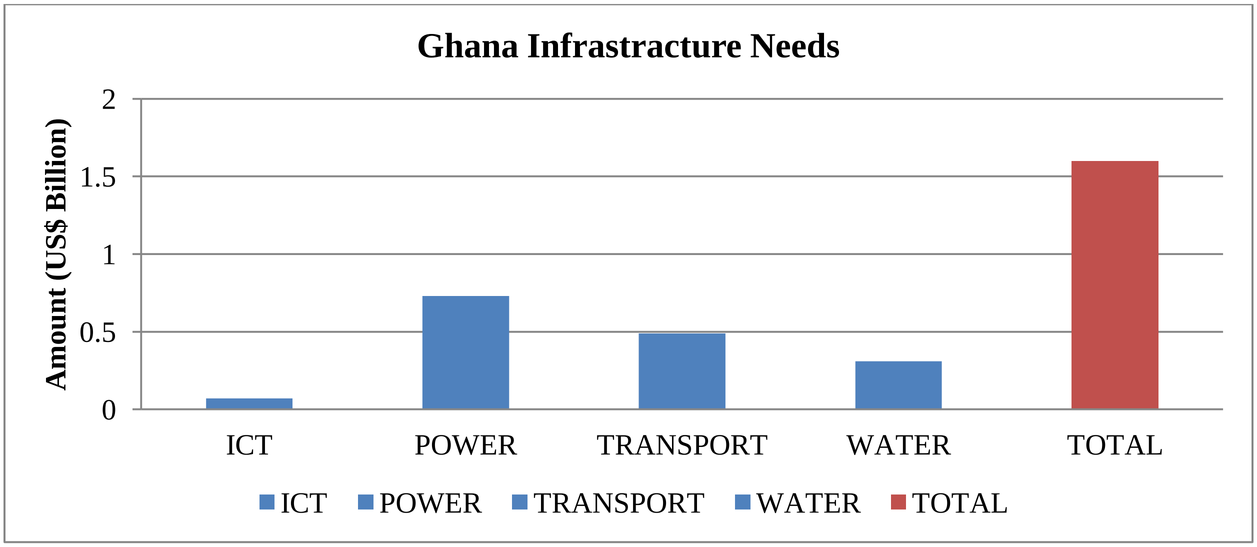
Table 7-7: Impact of fiscal rules on Industry, 2030

Sectors	Official 2010	Base run (Bil¢)	BIH	PI	GH
Mining	11.2%	5330.61	0.04%	9.13%	0.96%
Petroleum		402.582	0.26%	25.43%	3.04%
Construction	7.9%	12240.6	0.17%	16.38%	1.96%
Water	1.8%	207.219	0.40%	13.31%	1.270%
Electricity	16.7%	3404.25	0.89%	36.50%	4.35%

Source: Author based on Ghana's Computable General Equilibrium Model

Additional government spending must target infrastructure in the energy sector to meet the growing demand for energy and the construction subsector to reduce Ghana's housing deficit. Ghana is faced with a budget financing gap for infrastructure, estimated by the World Bank at US$1.6 billion annually as shown in the graph below.

Figure 7-1: Ghana Infrastructure Needs



Source: Africa Infrastructure Country Diagnostic.

Thus additional financing from petroleum revenues are expected to provide the needed impetus to reduce the financing gap. The energy sub-sector which is dominated by electricity production is also expected to grow in the long-term. The growth can come from increasing demand for electricity by households whose income levels have increased as a result of increased government expenditure. This attracts investments to the public utilities companies and from independent power producers to increase electricity generation capacity to meet the increasing demand. Demand for electricity in Ghana grows at an annual rate of 10% and is expected to increase further with increasing industry-led growth. Further, Government plans to increase generation capacity to 5000 MW by 2016 from 2400 in 2013 and further to 10,000 MW by 2025; which requires substantial public and private investments to realize.

The petroleum sub-sector records a very high long-term growth at 25%. This in part can be attributed to the rapid deregulation of the sector to encourage private sector investments.

Government expenditure has been observed to have significant impact on private consumption. Also, the substitution of petroleum revenues for domestic borrowing crowds in the private sector. Thus, increased private investment in the petroleum sector as a consequence of government's spending from petroleum revenues can derive the growth of the sector.

Another reason why increasing Government expenditure based on the permanent income model is that demand for petroleum increases as a result of increased income levels among households. The high demand for manufacturing products and transportation needs as a consequence of high incomes causes demand for petroleum to grow. Industries need electricity to produce which also depends on petroleum fired plants. The growth of the economy as a result of higher aggregate demand also puts pressure on the supply of petroleum. It is therefore expected that the long-term growth of the petroleum sector will come from increased supply of petroleum to meet the growing demand.

The construction subsector has also seen a surge in road construction. Government has prioritized road infrastructure investments and has committed the largest share of its petroleum revenues in the annual budget to finance this sector. From 2011-2013, more than 63 road infrastructure projects are being funded partly from petroleum revenues which are likely to continue into the long –term. These projects listed below received a total of GHS460, 045,037 of Ghana's share of petroleum revenues.

a. Upgrading of Sefwi Bekai-Eshiem-Asankragwa Road
b. Reconstruction of Asankragua-Enchi Road
c. Emergency Rehabilitation works on Dansoman main road
d. Rehabilitation of Anyinam-Konongo Road, Nkawkaw by-pass (Adden No.2)
e. Partial Reconstruction of Bomfa Junction-Asiwa and Bekwai-Ampaha Asiwa Road

f. Upgrading of Tainso-Badu-Adentia Road

g. Reconstruction of Berekum-Sampa Road (Km 32-88)

h. Construction of Kpando-Worawara Dambai Road Phase III

i. Emergency works on the upgrading of Ho – Adidome and Adaklu Xelekpe-Aduadi Road

j. Construction of Twifo Praso-Dunkwa Road

k. Construction of steel bridge over river Amunam and over River Kakum on Kwaprow-Ankaful Road

l. Reconstruction of Navrongo-Tumu Road

m. Construction of Wa-Han Road

n. Construction of Bamboi-Bole road (Bamboi-Tinga Section)

o. Accra-Kumasi Highway Dualisation Project: Kwafokrom – Apedwa Section

p. Reconstruction of Sunyani Road in Kumasi (Sofoline Interchange

These projects are expected to increase income levels of contractors, construction workers, construction material suppliers and their households which will further increase demand for other construction services such as housing. The permanent income model is the most suitable to generate the level of growth expected in the construction subsector because of its larger share of expenditure relative to the alternative rules.

The mining sub-sector growth will be limited and growing less than its 2010 growth. This is because the sector is private sector led and growth emanates from the investment environment that provides incentive for higher levels of investments. The introduction of new fiscal reforms including an increase in corporate taxes from 25% to 35%, introduction of a windfall tax of 10% and ring-fencing of costs are likely to further suppress the growth of the sector. These reforms are already shifting the investment location preference of mining companies. Goldfields Ghana

Limited threatened to abandon a US$1 billion mining projects as a result of these reforms (Reuters, “Goldfields reduces investments in Ghana”, 8 December 2011). If the Government does not change its disincentive regime largely caused by the rise of resource nationalism, there will be deceleration in the growth of the mining sector as is projected in this analysis.

7.2.3.3 Services Sector Growth

The services sub-sector post a long term impressive growth potential when public investment is increased from petroleum revenues. Consistent with previous analysis, the permanent income rule is associated with higher growth rates than the bird-in-hand and Ghana’s fiscal rules. The sector forms a significant large part of the economy and accounts for about a third of overall GDP. Services can be classified as public and private, traded and non-traded, high and low value; and capital intensive and labour intensive services.

Much of the sector’s long-term growth comes from trade (38%) and communications (30%). The simulation shows that there can be greater economic growth from the expansion of the services sector as demonstrated by Ghana’s recent growth in which the services sector contributed more to growth than agriculture and industry. Trade services cover external and internal services. Ghana’s service sector has been largely associated with internal trade services which are dominated by the informal sector. This analysis did not include the informal sector of the economy in the model, but when developed through government intervention in infrastructure provision, it could be the driving force behind the growth of the services sector. Growth in trade services can be generated from the impact of increased government expenditure on the demand side. This is largely because the economy is more of a commercial one than a productive one.

The commercial frameworks of the economy are further supported by the growing import levels. Trading services such as buying and selling of domestic substitutable import commodities will in future negatively affect domestic production and its implications for export growth is well known. It must be noted that trade in Ghana cannot be divorced from its linkage with external trade as most commodities are imported from abroad.

Also significant is communications service. This is also influenced by the increasing market for mobile phone services and internet services. The communication sub-sector has grown fast over the last decade with the entry into Ghana of 6 telecommunication service companies – Airtel, Tigo, Vodafone, Kasapa, Glo and MTN. The demand for these services increases with increasing income levels. Thus, the spending of petroleum revenues could provide the impetus for further growth of the sub-sector in the long-term.

Table 7-8: Impact of fiscal rules on Services, 2030

Sectors	**Official 2010**	**Base run (Bil ¢)**	**BIH**	**PI**	**GH**
Trade	9.1%	5949.24	0.39%	37.83%	4.53%
Communications	19.6%	2199.23	0.32%	30.07%	3.71%
Public Admin	7.6%	14682.7	0.00%	6.23%	0.63%
Education	7.1%	3115.33	0.00%	5.31%	0.04%
Health	8.2%	911.317	0.03%	7.12%	0.87%

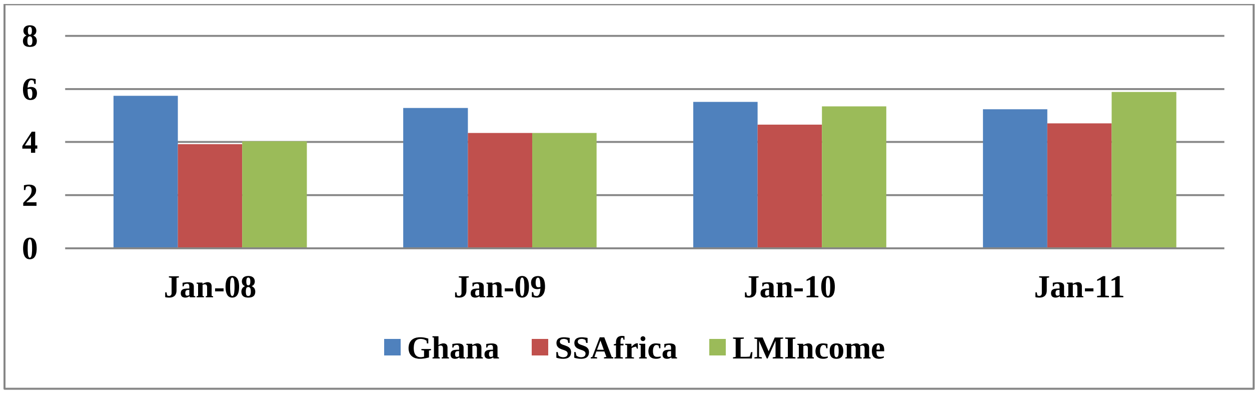
Source: Author based on Ghana's Computable General Equilibrium Model

Public administration, education and health services are unlikely to grow beyond their 2010 levels. The slow growth in public administration is as a result of a freeze in public sector employment. There have been several efforts at improving the efficiency of the public sector through policy and resources from both government and development partners. Weak institutions and low absorptive capacity do not support the efficiency of public spending and value for money consideration. Thus, irrespective of the type of fiscal rule, petroleum revenues and increased public investments will not generate the desired growth if the regulatory and institutional arrangements are not sufficiently resourced with technical and financial capacity.

The low impact of general public spending on education and health means that unless these important social sectors are specifically targeted, other components of public spending are likely to absorb higher proportion of public expenditure at the expense of productivity and income distribution associated with human capital development. Fan et al, (1999) show that public expenditure on health and education has visible impacts on poverty. Further, expenditure on education has the largest impact on poverty reduction in China (Fan et.al, 2002). Thus, targeting of public resource allocation to primary education in particular and health could largely improve on the distribution of human capital and income distribution (Jose, 1998).

Productivity enhancement is an important requirement for economic growth. Further, human capital development is the most equitable way of distributing the benefits of petroleum revenues through public spending. It is also the foundation for developing the productive factors to support economic growth in the long-term. This has serious implications for Ghana's middle income status. However, the growth of public investment in social services is declining in Ghana.

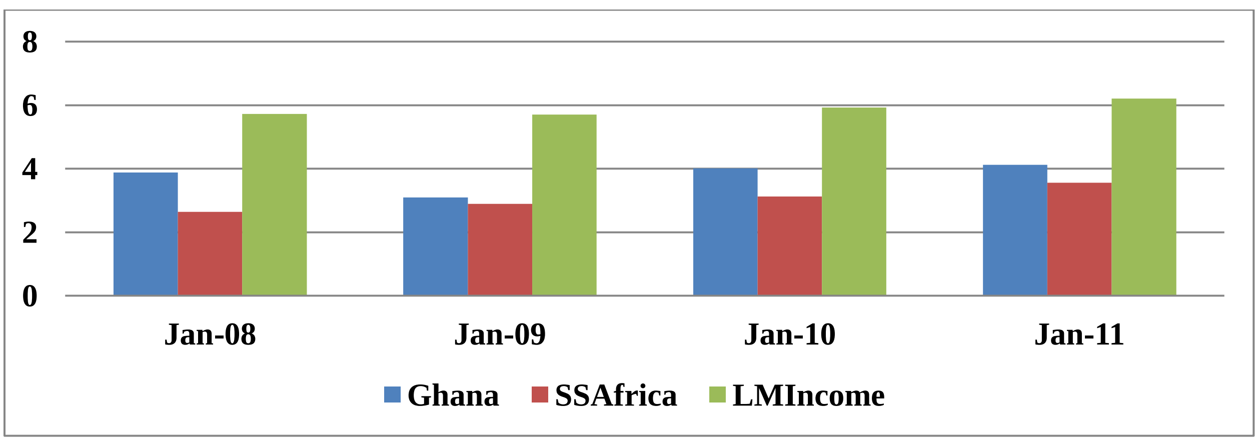
Figure 7-2: Public Spending on Education by the Government of Ghana (%GDP)



Source: Source: CIA Fact-book 2012.

Figure 7-2 above shows that Ghana's public spending on education as a proportion of GDP has been declining to the levels below lower middle income average, indicating that Ghana could be spending lower than her peers in the lower middle income category (Adam et al, 2013). Public spending on health is also lower than lower middle income average.

Figure 7-3: Public Spending on Health by the Government of Ghana (%GDP)



Source: CIA Fact-book 2012.

The analysis in this study reignites the debate over the long-term growth potential of education and health financing. For instance the simulation shows that education sector growth in 2030 with the permanent income model lags behind its 2010 level. The health sector long-term growth follows this trend. This is possible because the marginal benefits of spending on education and health decreases rapidly in middle income countries (Gupta et al, 2004). The simulation demonstrates that Ghana can consolidate its middle income status by 2030, which could have decelerating effect on the marginal growth in education and health services.

7.3 Impacts of the Efficiency of Fiscal rules on the Economy

This section analyzes the impact of the efficiency of fiscal rules in the economy. Fiscal rules by nature do not factor in efficiency parameters but only guide the level of expenditure distribution. However, such expenditure distribution does not guarantee sustainable development outcomes.

To measure the efficiency of fiscal rules, a representative efficiency index – the institutional quality index - adopted from the World Bank's Country Policy and Institutional Assessment (CPIA) was introduced in the simulation model. Institutional quality is an important measure of the efficiency of public spending (World Bank, 2009). Dombusch (1993) argues that no economic principles can improve the lot except a change of culture, improved discipline, and transparency and do away with corruption, which are institutional benchmarks for improving on resource allocation.

The index used in this analysis was applied to the permanent income rule which demonstrated ability to contribute significantly to the long-term growth of the economy. The results of the simulations on the productive sectors are shown as follows:

Table 7-9: Impacts of the Efficiency of Fiscal rules on Development, 2030

Sectors	**Base run (Bil¢)**	**Permanent Income**	**Efficiency Gains**	
			CPIA =3	**CPIA = 6**
Cocoa Beans	2517.798	6.8%	0.28%	0.37%
Forestry	59.63	5.34%	0.15%	0.23%
Fisheries	1695.7	6.38%	0.10%	0.14%
Mining	5330.61	9.13%	0.02%	0.03%
Petroleum	402.582	25.43%	0.12%	0.19%
Construction	12240.6	16.38%	0.09%	0.13%
Water	207.219	13.31%	0.19%	0.29%
Electricity	3404.25	36.50%	0.39%	0.62%
Trade	5949.24	37.83%	0.20%	0.30%
Communications	2199.23	30.07%	0.15%	0.24%
Public Admin	14682.7	6.23%	0.00%	0.01%
Education	3115.33	5.31%	0.00%	0.01%
Health	911.317	7.12%	0.00%	0.02%

Source: Author based on Ghana's Computable General Equilibrium Model

In this analysis, and as already indicated, CPIA index 3 represents moderately weak institutions and CPIA index 6 represents very strong institutions. The simulation shows that strong institutions can improve on the efficiency of fiscal rules and public spending through efficiency gains. Efficiency gains associated with very strong institutions are greater than those of moderately weak institutions (See Table 7-9 above). For instance, the simulation shows that a higher CPIA could lead to higher efficiency gains for the health sector (0.02%) than a lower CPIA score. The simulation results in this case confirms the work by Wagstaff and Claeson (2004) who found that the elasticity of health outcomes to expenditure was directly related to a country's CPIA score.

Weak institutions create opportunity for patronage as opposed to quality; vested interest as opposed to general interest; elite societies as opposed to welfare societies. Where natural resource wealth is managed with weak institutions, the wealth is used to entrench the interest of their owners to keep institutions weaker (Isakova et.al, 2012). They also weaken institutions such as media freedom (Egorov, Guriev and Sonin, 2009), democratic institutions (Ross, 2001), and the business climate for medium-sized businesses in the non-resource sectors (Amin and Djankov, 2009).

It must be noted that as an oil producing country, public spending objectives may be undermined because increasing dependence on these resources largely remove the need to raise revenue from growth enhancing industries such as manufacturing and agriculture, which may relax government discipline in terms of efficiency of public spending and quality of public services (Karl, 1997). Thus, the low quality of services in education and health might be matched against eroding discipline in public spending as a consequence of weakening institutions.

It is also important to note that the contribution of public investments to the economy depends on the quality of investment projects selection, feasibility, quality of procurement and delivery of projects and services; which are determined by the strength and capacity of state institutions. If attention is not paid to these factors, public spending promotes wastefulness and squanders development opportunities.

It has even been suggested that efficiency gains need to be weighed against distributive concerns since such gains could have greater development impacts in the long-term than short–term distributive effects. In other words, the “benefit incidence”, those who benefit from public services and the “expenditure incidence”, the extent to which public spending affects private incomes, are important considerations for determining the development impacts of allocating spending. However, most resource-rich countries are more concerned about the benefits which suffer from the effects of short-termism. It is important to measure the incidence of public spending on desired development outcomes to ensure that the long-term impacts of spending are achieved (Rathin et al, 2009). An efficient allocation of resources ensures that public spending maximizes the desired welfare outcomes. The growth of the various sectors of production shows that institutional quality has a great impact on expenditure outcomes. Their contribution to the economy increases with a CPIA of 6, and decreases with a CPIA of 3.

7.4 Conclusions

This section provides analyses of simulation results conducted on Ghana’s CGE model. It shows that whilst fiscal rules are important in an economy, not all of them can affect economic development greatly.

Of the alternative fiscal rules, the permanent income rule offers the highest development impact on the economy, followed by Ghana’s fiscal rule and then by the bird-in-hand rule. This is contrary to the fiscal sustainability analysis which finds the bird-in-hand rule most fiscally sustainable. This means that fiscal sustainability does not necessarily lead to higher development impacts. Thus, whilst the permanent income rule might not be fiscally sustainable in the long-term relative to the bird-in-hand rule, its impact on the economy is greater because of high early consumption. The permanent income therefore could consolidate Ghana’s transformation towards a middle income status. Ghana therefore has a choice between fiscal sustainability and development impacts but not both. That is, whether to adopt the bird-in-hand rule or the permanent income rule.

However, Ghana’s own current rule neither proves to be fiscally sustainable nor guarantees high development impacts relative to the alternative rules. The analyses also reveals that the level of institutional quality in a country could lead to efficiency gains in government spending, and that such gains are necessary to improve on the development impacts of fiscal rules.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

The objectives of the study are to assess the fiscal sustainability of Ghana's fiscal rule against alternative fiscal rules and their impacts on economic development. The study also examines the effects of fiscal efficiency. In response to the research questions, three levels of analyses have been conducted.

In the first analysis simple fiscal sustainability tools are used to explain the sustainability of the permanent income, bird-in-hand and Ghana's fiscal rules whilst in the second, a dynamic CGE model is applied to assess the development impacts of fiscal rules. In the third analysis, development impacts of the efficiency of fiscal rules have been examined. The CGE model follows the model developed by Logfren et.al (2002) to analyze the economy-wide effects of policies in developing countries but the Mathematical presentation of the model is adopted from Briesinger et al, (2011) and modified to capture institutional arrangements in explaining the efficiency of policy tools on an economy, an element which has been ignored in the traditional CGE literature. The World Bank's Country Policy and Institutional Assessment (CPIA) Index is adopted as proxy for institutional quality and represents a measure of fiscal efficiency.

Generally, the study makes four important findings on how fiscal policy triggered by the inflow of new petroleum revenues could affect the long-term fiscal sustainability and growth of the economy.

a. Ghana's fiscal rule is neither fiscally sustainable nor provide higher impacts of petroleum revenues on economic development relative to the permanent income and the bird-in-hand rules. Further, Ghana's fiscal rule is more pro-cyclical, it increases public spending with increasing oil production and the reverse is true.

b. Fiscal sustainability does not necessarily lead to greater development outcomes. The bird-in-hand rule is the most fiscally sustainable, but the permanent income rule provides higher development outcomes. Thus, whilst the permanent income rule might not be fiscally sustainable in the long-term, its impact on the economy is greater because of high early consumption and has the potential to move Ghana's transformation towards a full middle income status.
c. Institutional quality in a country could lead to efficiency gains in government spending.
d. Efficiency in government spending can lead to improvement in development outcomes.

8.2 Fiscal Sustainability in Ghana under alternative Fiscal rules

The study examines the extent to which each of three alternative fiscal rules – permanent income, bird-in-hand and Ghana's rules are fiscally sustainable. Fiscal sustainability is explained in terms of the fiscal benchmarks computed from alternative fiscals measured as a proportion of GDP.

The study shows that Government consumption in the country could be sustained at different levels depending on total government consumption and oil induced consumption. For instance, the study reveals that the bird in hand rule promises relative sustainability because it offers the highest government consumption levels proportional to GDP after oil depletion period compared with the permanent income rule and Ghana's fiscal rule. The permanent income rule offers higher early consumption whilst Ghana's rule provides higher consumption during peak oil production. Thus, Ghana's rule and Permanent Income can finance relatively higher non-oil fiscal deficits in the short-to-medium term than their counterpart Bird-in-hand rule. However, in the long-term the Bird-in-hand rule can allow for higher fiscal adjustments.

The study also concludes that the adoption of Ghana's rule does not only reduce the ability of petroleum revenues to finance higher deficits in the long-run, but also narrows the future fiscal space in the economy with serious implications for financing sustainable consumption.

The Government must take a number of fiscal policy decisions to address the short, medium and long term fiscal challenges that have the tendency of weakening the economy.

a. Fiscal discipline and prudence for the effective management of financial assets especially if rules based fiscal policy is implemented. Financial crises could particularly plunder returns on financial assets and slow down the growth of the petroleum funds which puts fiscal sustainability in danger. It is therefore important to institute a convenient combination of savings and investment rules that allow for investment of revenues in productive infrastructure while saving some of the revenue in low risk assets.

b. Social welfare volatilities associated with rising and falling consumption pattern are likely to increase social disaffection. While the permanent income and Ghana rule may be preferable in the short to medium term because of their relatively higher levels of consumption, their long-term sustainability is questionable. The solution to the problems of social disaffections associated with fiscal sustainability policy rests with the political economy of managing natural resources. The Government must therefore involve the people and ensure greater understanding among them of the implications of heavy current consumption versus future consumption or vice versa. This could limit social disaffections for the Government and the burden it could put on the economy.

c. There is the tendency to rely on fiscal sustainability without addressing the structural causes of inefficiency and wasteful public spending. Government must control spending and improve on the efficiency of public spending and domestic revenue mobilization by instituting far reaching public sector reforms.

8.3 Development impact of Fiscal rules in Ghana

The effects of an increase in government expenditure based on fiscal rules are measured on macroeconomic variables, factor incomes, household consumption expenditure and the productive sectors of the economy.

Under all the alternative fiscal rules, GDP (value added) shows consistent growth pattern from the short to long- term. However, the long-term GDP growth associated with the permanent income rule is much higher, 10% by 2030 compared to 0.1% and 1.2% for the bird-in-hand and Ghana's fiscal rules respectively. From the macroeconomic perspective, this growth is fuelled by growth in private consumption (10.9%), fixed investments (14.8%) and exports (17.9%).

Another important finding from the simulations is that Ghana can experience structural transformation in the economy. This is because, the growth of the productive sectors of the economy in the long-run may be influenced more by industry led by electricity (37%), petroleum (25%) and construction (16%) subsectors. This is followed by services led by trade (38%) and communications (30%); and then by the agriculture sector led by cocoa (7%).

The permanent income rule also offers higher returns on the long-term growth in factor incomes for all factor inputs. However, skilled non-agricultural labour in labour intensive sectors make the most gains indicating that investment focus should be on labour intensive industries.

Thus, whilst the permanent income rule might not be fiscally sustainable in the long-term, its impact on the economy is greater because of high early consumption. The permanent income therefore could consolidate Ghana's transformation towards a middle income status.

One of the important findings is that household expenditure can grow in the long-term. The study shows that the expenditure of urban households is higher than that of the rural households. The implications from this finding are that development from the spending of petroleum revenues may not be fairly distributed between urban and rural populations; and this could increase the influx of rural populations to the urban areas. Also, urban North household's expenditure grows faster alongside Accra households, indicating the potential for bridging the development gap between the Northern and Southern parts of Ghana.

Finally, the study shows that institutional quality is an important measure of efficiency and is an important requirement for improving on the efficiency of government spending. Efficiency gains in government spending could improve on the development outcomes of government fiscal policy. The important implication of this finding for policy makers is that a country can overcome the factors that impede the translation of resource abundance into positive development outcomes if good institutions are built and maintained whilst systems that improve on the management of revenues from the exploitation of petroleum resources (or minerals) are put in place.

8.4 Some Main Recommendations

The Government of Ghana should consider the following recommendations to guide its spending of petroleum revenues to ensure greater development outcomes.

a. The Government of Ghana should change its current fiscal rule for spending petroleum revenues and adopt the permanent income rule as it offers higher development outcomes.

This recommendation is however necessary but not sufficient since fiscal rules by themselves cannot translate petroleum revenues to positive development outcomes in a weak institutional environment.

b. Government must invest in building strong and independent institutions, improve on the policy formulation processes and project implementation effectiveness. This enhances the efficiency of public spending as already demonstrated from the study. These require interventions including new legislative frameworks, effective implementation of existing legislation and enhanced transparency and accountability regime to govern the inflows and outflows of petroleum revenues. Some specific interventions are prescribed as follows:

i. Budgetary control and fiscal discipline require strong institutional frameworks that provide credibility and predictability to fiscal management issues. To this end, the Government must initiate important legislations such as the Fiscal Responsibility Act and the Budget Act. The Budget Act should among others establish a Budget Office in Parliament to monitor compliance with the Fiscal Responsibility Act.

ii. Problems associated with public financial management have undermined institutional quality and increased the vulnerability of public resources to abuse through corruption, mismanagement and low investment returns. Government must therefore spend petroleum revenues guided by a long-term national development plan. In addition, Government must initiate legislation on Public Investment Management to guide project selection, procurement and timely execution of projects. This will ensure efficiency gains and lead to value for money for projects funded with both oil and non-oil revenues.

iii. Public accountability raises public confidence in the Government's ability to manage pubic resources. This however requires significant level of transparency. The Petroleum Revenue Management Act 2011 has already provided for extensive transparency including a requirement for the publication of petroleum receipts, distribution of petroleum revenues and the expenditure on development interventions. It also creates the Public Interest and Accountability Committee with responsibility to provide independent assessment of the uses of petroleum revenues. These measures are not exhaustive as the Committee is not adequately funded, and which has undermined its effectiveness in monitoring the uses of petroleum revenues. It is therefore important to complement these transparency and accountability measures with the passing into law of the Right to Information Bill currently pending in Parliament. This will provide public interest information to citizens for the purpose of demanding accountability of the Government. Civil society has become an important institution replacing weak public institutions in most cases. Civil society organizations must therefore be supported with technical capacity to debate national policies on the use of petroleum revenues for accelerated development.

iv. Transparency and accountability mechanisms should facilitate fiscal expansion from petroleum resource exploitation. Thus the Government should incorporate transparent frameworks such as open and competitive bidding process for granting petroleum concessions, mandatory disclosure of petroleum agreements and other contracts; and the disclosure of beneficial ownership information. This ensures public accountability and facilitates the building of strong institutions to oversee management of petroleum resources and revenues generated from the resources.

8.5 Limitations of the Study and Recommendations for Future Research

The study is limited in several ways. Some of the limitations are explained as follows. The model assumed full-employment in the economy. However, as a developing country, Ghana has not reached the state of full-employment. The introduction of unemployment in the model in future will likely improve on the results of the study.

There are several measures of institutional quality and there is no consensus on the type or size of institutions that could well interpret a measure of institutionalism. It may be interesting to adopt a similar model with a different indicator of institutional quality such as the World Bank's Global Governance Indicators to see if the results will be different.

The Ghana CGE model focused on the real side of the economy in which only relative prices are important; and ignores the impact of financial markets. The adoption of financial models with institutional quality will also be appropriate.

APPENDICES

Appendix 1-A

Computation of Permanent Income Value (Scenario 1 - $110/bbl; r = 0.03)

YEAR	Pet Rev	Non Pet Rev	PI	Oil Rev (PI)
2010	6.372	4946.501329	5523.012236	576.5109064
2011	313.4225	8278.185221	8278.195221	576.5109064
2012	327.1613	9677.650933	10254.16184	576.5109064
2013	548.4215	11979.26312	12555.77403	576.5109064
2014	427.6892	14060.78125	14637.29216	576.5109064
2015	480.5328	16395.31293	16971.82384	576.5109064
2016	2038.139	18545.54383	19122.05474	576.5109064
2017	3742.481	20996.91551	21573.42641	576.5109064
2018	5797.493	23726.13517	24302.64608	576.5109064
2019	7730.191	26578.53192	27155.04283	576.5109064
2020	10762.58	29788.38292	30364.89383	576.5109064
2021	4930.396	33434.3816	34010.8925	576.5109064
2022	4752.658	37618.51889	38195.02979	576.5109064
2023	4325.077	42370.30209	42946.813	576.5109064
2024	3899.811	47772.54313	48349.05404	576.5109064
2025	3433.51	53920.95203	54497.46294	576.5109064
2026	2968.495	60926.2596	61502.77051	576.5109064
2027	2631.321	68916.70509	69493.216	576.5109064
2028	2293.155	78040.95376	78617.46466	576.5109064
2029	2042.31	88615.85512	89192.36602	576.5109064
2030	1788.084	100686.5208	101263.0317	576.5109064

Appendix 1 – B

Computation of Bird-in-Hand Value (Scenario 1 - $110/bbl; r = 0.03)

Year	Non Pet Rev	Pet Rev	r*Opening Bal	BIH(Discounted)	BIH (Undiscounted)
2010	4946.501329	6.372	0.19116	5347.468934	4946.692489
2011	8278.185221	313.42245	9.5995683	8679.152826	8287.784789
2012	9677.650933	327.161325	19.7023951	10078.61854	9697.353328
2013	11979.26312	548.421525	36.7461127	12380.23073	12016.00923
2014	14060.78125	427.68921	50.67917238	14461.74886	14111.46043
2015	16395.31293	480.532785	66.6155311	16796.28054	16461.92846
2016	18545.54383	2038.139113	129.7581704	18946.51144	18675.302
2017	20996.91551	3742.480633	245.9253345	21397.88311	21126.67368
2018	23726.13517	5797.493279	427.2278929	24127.10278	24153.36307
2019	26578.53192	7730.191169	671.9504648	26979.49953	27250.48239
2020	29788.38292	10762.58462	1014.986517	30189.35053	30803.36944
2021	33434.3816	4930.395607	1193.347981	33835.3492	34627.72958
2022	37618.51889	4752.65774	1371.728153	38019.48649	38990.24704
2023	42370.30209	4325.077092	1542.63231	42771.2697	43912.9344
2024	47772.54313	3899.811292	1705.905618	48173.51074	49478.44875
2025	53920.95203	3433.510352	1860.088097	54321.91964	55781.04013
2026	60926.2596	2968.494543	1950.678249	61327.22721	62876.93785
2027	68916.70509	2631.320632	2088.138215	69317.6727	71004.84331
2028	78040.95376	2293.155217	2219.577018	78441.92136	80260.53077
2029	88615.85512	2042.309755	2347.433621	89016.82272	90963.28874
2030	100686.5208	1788.083511	2471.499135	101087.4884	103158.0199
r =		0.03			
Discounted Returns =		13365.58684			
r*Discounted returns =		400.9676053			
BIH = r*Discounted returns + Non Pet Rev					

Appendix 1 – C

Computation of Ghana's Fiscal Rule Value (Scenario 1 - $110/bbl; r = 0.03)

Year	Non Pet Rev	Pet Rev	GNPC	Benchmark	ABFA	GH
2010	4946.501	6.372	2.99484	3.37716	2.364012	4948.86534
2011	8278.185	313.4225	147.3086	166.1138985	116.2797	8394.46495
2012	9677.651	327.1613	153.7658	173.3955023	121.3769	9799.02778
2013	11979.26	548.4215	257.7581	290.6634083	203.4644	12182.7275
2014	14060.78	427.6892	201.0139	226.6752813	158.6727	14219.4539
2015	16395.31	480.5328	225.8504	254.6823761	178.2777	16573.5906
2016	18545.54	2038.139	957.9254	1080.21373	756.1496	19301.6934
2017	20996.92	3742.481	1758.966	1983.514735	1388.46	22755.8814
2018	23726.14	5797.493	2724.822	3072.671438	2150.87	25877.0052
2019	26578.53	7730.191	3633.19	4097.00132	2867.901	29446.4328
2020	29788.38	10762.58	5058.415	5704.169849	3992.919	33781.3018
2021	33434.38	4930.396	986.0791	3944.316485	2761.022	36195.4031
2022	37618.52	4752.658	950.5315	3802.126192	2661.488	40280.0072
2023	42370.3	4325.077	865.0154	3460.061673	2422.043	44792.3453
2024	47772.54	3899.811	779.9623	3119.849033	2183.894	49956.4375
2025	53920.95	3433.51	686.7021	2746.808281	1922.766	55843.7178
2026	60926.26	2968.495	593.6989	2374.795635	1662.357	62588.6165
2027	68916.71	2631.321	526.2641	2105.056506	1473.54	70390.2446
2028	78040.95	2293.155	458.631	1834.524174	1284.167	79325.1207
2029	88615.86	2042.31	408.462	1633.847804	1143.693	8975955%
2030	100686.5	1788.084	357.6167	1430.466808	1001.327	101687.848

Appendix 1 – D

Sustainable Fiscal Constraint base on Overall Government Budget with petroleum Revenues

YEAR	PI	BIH	GH	GDP	PI(%GDP)	BIH(%GDP)	GH(%GDP)
2010	6307.887	4946.692	4948.865	44465.41	0.141861	0.11124811	0.111296979
2011	8278.215	8287.785	8394.465	56225.79	0.147232	0.14740183	0.149299181
2012	11039.04	9697.353	9799.028	65558.1	0.168386	0.14791999	0.149470896
2013	13340.65	12016.01	12182.73	75545	0.176592	0.15905764	0.161264516
2014	15422.17	14111.46	14219.45	87990.53	0.175271	0.16037476	0.161602096
2015	17756.7	16461.93	16573.59	101985.6	0.17411	0.16141427	0.162509156
2016	19906.93	18675.3	19301.69	114347.8	0.174091	0.16332017	0.168798122
2017	22358.3	21126.67	22755.88	128165.1	0.174449	0.16483954	0.177551325
2018	25087.52	24153.36	25877.01	143710.7	0.17457	0.1680693	0.180063129
2019	27939.92	27250.48	29446.43	159903.6	0.17473	0.17041817	0.184151129
2020	31149.77	30803.37	33781.3	178223.4	0.174779	0.17283574	0.189544732
2021	34795.77	34627.73	36195.4	199258	0.174627	0.17378338	0.181650939
2022	38979.9	38990.25	40280.01	223419	0.17447	0.17451623	0.180289057
2023	43731.69	43912.93	44792.35	250971.7	0.174249	0.17497167	0.17847569
2024	49133.93	49478.45	49956.44	282408.6	0.173982	0.17520161	0.17689415
2025	55282.34	55781.04	55843.72	318198.5	0.173735	0.17530265	0.175499624
2026	62287.64	62876.94	62588.62	358979.2	0.173513	0.1751548	0.174351629
2027	70278.09	71004.84	70390.24	405489.9	0.173317	0.17510879	0.173593093
2028	79402.34	80260.53	79325.12	458744.5	0.173086	0.17495694	0.172917874
2029	89977.24	90963.29	89759.55	520453.4	0.172882	0.17477701	0.17246414
2030	102047.9	103158	101687.8	591027.1	0.172662	0.17454026	0.172052771

Appendix 1 – E

Sustainable Fiscal Constraint based on petroleum Revenues as Additional Source of Expenditure

YEAR	PI	BIH	GH	GDP	PI (%GDP)	BIH %GDP)	GH (%GDP)
2010	1361.3852	0.19116	2.364012	44465.41	0.030617	4.29907E-06	5.31652E-05
2011	1361.3852	9.5995683	116.279729	56225.79	0.024213	0.000170732	0.002068085
2012	1361.3852	19.7023951	121.3768516	65558.1	0.020766	0.000300533	0.001851439
2013	1361.3852	36.7461127	203.4643858	75545	0.018021	0.000486414	0.002693287
2014	1361.3852	50.6791724	158.6726969	87990.53	0.015472	0.000575962	0.001803293
2015	1361.3852	66.6155311	178.2776632	101985.6	0.013349	0.000653186	0.001748067
2016	1361.3852	129.75817	756.1496108	114347.8	0.011906	0.001134768	0.006612717
2017	1361.3852	245.925335	1388.460315	128165.1	0.010622	0.001918817	0.010833374
2018	1361.3852	427.227893	2150.870006	143710.7	0.009473	0.002972832	0.014966662
2019	1361.3852	671.950465	2867.900924	159903.6	0.008514	0.004202222	0.017935184
2020	1361.3852	1014.98652	3992.918894	178223.4	0.007639	0.005695025	0.022404013
2021	1361.3852	1193.34798	2761.02154	199258	0.006832	0.005988959	0.013856515
2022	1361.3852	1371.72815	2661.488334	223419	0.006093	0.00613971	0.011912541
2023	1361.3852	1542.63231	2422.043171	250971.7	0.005424	0.006146639	0.009650663
2024	1361.3852	1705.90562	2183.894323	282408.6	0.004821	0.006040557	0.0077331
2025	1361.3852	1950.67825	1922.765797	318198.5	0.004278	0.006130382	0.006042661
2026	1361.3852	1950.67825	1662.356944	358979.2	0.003792	0.005433958	0.004630788
2027	1361.3852	2088.13821	1473.539554	405489.9	0.003357	0.005149668	0.003633974
2028	1361.3852	2219.57702	1284.166922	458744.5	0.002968	0.004838373	0.002799308
2029	1361.3852	2347.43362	1143.693463	520453.4	0.002616	0.004510363	0.002197494
2030	1361.3852	2471.49914	1001.326766	591027.1	0.002303	0.004181702	0.001694215

Appendix 1 – F

Sensitivity Analysis of a Change in Crude Oil Price

Year	PI@$110/bbl(%GDP)	PI@$90/bbl(%GDP)	PI@$70/bbl(%GDP)
2010	0.030616727	0.025513939	0.020411151
2011	0.024212823	0.020177353	0.016141882
2012	0.020766087	0.017305073	0.013844058
2013	0.018020852	0.015017376	0.012013901
2014	0.015471951	0.012893293	0.010314634
2015	0.013348801	0.011124001	0.008899201
2016	0.011905653	0.009921377	0.007937102
2017	0.010622122	0.008851768	0.007081415
2018	0.009473093	0.007894244	0.006315395
2019	0.008513786	0.007094821	0.005675857
2020	0.007638646	0.006365538	0.00509243
2021	0.006832274	0.005693561	0.004554849
2022	0.006093416	0.005077847	0.004062278
2023	0.005424457	0.004520381	0.003616305
2024	0.004820622	0.004017185	0.003213748
2025	0.004278415	0.003565346	0.002852277
2026	0.003792379	0.003160315	0.002528252
2027	0.003357384	0.00279782	0.002238256
2028	0.002967633	0.002473027	0.001978422
2029	0.002615768	0.002179806	0.001743845
2030	0.002303423	0.001919519	0.001535615

Appendix 1 – G

Sensitivity Analysis of a change in Interest Rate

Year	PI@$110/bbl; r=0.06 (%GDP)	PI@$110/bbl; r=0.03 (%GDP)	PI@$110/bbl; r=0.01 (%GDP)
2010	0.043569396	0.030616727	0.01296538
2011	0.034456266	0.024212823	0.010253495
2012	0.029551359	0.020766087	0.008793893
2013	0.025644728	0.018020852	0.007631358
2014	0.022017493	0.015471951	0.006551965
2015	0.018996126	0.013348801	0.005652867
2016	0.016942442	0.011905653	0.005041732
2017	0.015115902	0.010622122	0.00449819
2018	0.013480766	0.009473093	0.004011606
2019	0.012115616	0.008513786	0.003605365
2020	0.01087024	0.007638646	0.003234766
2021	0.009722726	0.006832274	0.002893289
2022	0.008671288	0.006093416	0.002580402
2023	0.00771932	0.005424457	0.002297115
2024	0.006860027	0.004820622	0.002041407
2025	0.006088435	0.004278415	0.001811796
2026	0.005396777	0.003792379	0.001605973
2027	0.004777754	0.003357384	0.001421764
2028	0.004223115	0.002967633	0.001256715
2029	0.003722391	0.002615768	0.001107709
2030	0.003277905	0.002303423	0.000975439

Appendix 2 – A

Mathematical Presentation of CGE Model: Model Equations

Production and price equations

$QINT_{ca} = ica_{ca} . QINTA_a$

$PINTA_a = \sum_{c\epsilon C} PQ_c \ . ica_{ca}$

$QVA_a = \alpha_a^{va} . \left(\sum_{f\epsilon F} \delta_{f\,a}^{va} . \ (\alpha_{f\,a}^{vaf} \ . \ QF_{f\,a})^{-p_a^{va}}\right)^{-1/} p_a^{va}$

$WF_f \ . \overline{WFDIST}_{fa} = PVA_a . QVA_a . \ \left(\sum_{f\epsilon F} \delta_{f\,a}^{va} . \ (\alpha_{f\,a}^{vaf} \ . \ QF_{f\,a})^{-p_a^{va}}\right)^{-}$

$^{1}. \ \delta_{f\,a}^{va} . \ (\alpha\alpha_{f\,a}^{vaf})^{-p_a^{va}} . (Q_{f\,a})^{-p_a^{va}-1}$

$QVA_a = iva_a . \ QA_a$

$QINTA_a = inta_a . \ QA_a$

$PA_a . \ (1 - ta_a) . \ QA_a = PVA_a . \ QVA_a + PINTA_a . \ QINTA_a$

$QXAC_{ac} = \theta_{a\,c} . \ QA_a$

$PA_a = \sum_{c\epsilon C} PXAC_{ac} . \ \theta_{ac}$

$QX_c = \alpha_c^{ac} . \ (\sum_{a\,\epsilon A} \delta_{a\,c}^{ac} . QXAC_{a\,c}^{-p_c^{ac}})^{-\frac{1}{p_c^{ac-1}}}$

$PXAC_{a\,c} = PX_c . \ QX_c \ (\sum_{a\epsilon A'} \delta_{a\,c}^{ac} . \ QXAC_{a\,c}^{vaf})^{-1} . \ \delta_{a\,c}^{ac} . \ QXAC_{a\,c}^{-p_c^{ac}-1}$

$PE_{cr} = pwe_{cr} . \ EXR - \sum_{c'\epsilon CT} PQ_c \ . ice_{c'c}$

$QX_c = \alpha_c^t . \ (\sum_r \delta_{cr}^t . \ QE_{cr}^{p_c^t} + \ [1 - \sum_r \delta_{cr}^t] \ . \ QD_{cr}^{p_c^t})^{1/p_c^t}$

$\frac{QE_{cr}}{QD_c} = \ (\frac{PE_{cr}}{PD_c} . \ \frac{1 - \sum_r \delta_{cr}^t}{\delta_c^t})^{-1/p_c^t - 1}$

$QX_c = QD_c + \sum_r QE_{cr}$

$PX_c . \ QX_c = PD_c . \ QD_c + \sum_r PE_{cr} . \ QE_{cr}$

$PM_{cr} = pwm_{cr} \ . (1 + tm_{cr}) . \ EXR + \sum_{c'\epsilon CT} PQ_{c'} . \ icm_{c'c}$

$$QQ_c = \alpha_c^q . (\textstyle\sum_r \delta_{cr}^q . \ QM_{cr}^{-p_c^q} + \left[1 - \sum_r \delta_{cr}^q\right] . QD_c^{-p_c^q})^{-1/p_c^q}$$

$$\frac{QM_{cr}}{QD_c} = (\frac{PD_c}{PM_c} . \ \frac{\delta_c^q}{1 - \sum_r \delta_{cr}^q})^{-1/1+p_c^q}$$

$$QQ_c = QD_c + \textstyle\sum_r QM_{cr}$$

$$PQ_c . \ (1 - tq_c) . \ QQ_c = PD_c . \ QD_c + \textstyle\sum_r PM_{cr} . \ QM_{cr}$$

$$cpi = \textstyle\sum_{c \epsilon C} PQ_c . \ cwts_c$$

Institutional incomes and domestic demand equations

$$YF_f = \textstyle\sum_{a \epsilon A} WF_f . \ wfdist_{f\,a} . \ QF_{f\,a}$$

$$YIF_{i\,f} = shif_{i\,f} . \ YF_f$$

$$YI_i = \textstyle\sum_{f \epsilon F} YIF_{i\,f} + \sum_{i' \epsilon\, INSDNG'} TRII_{ii'} + trnsfr_{i\,gov} . \ cpi + trnsf_{i\,row} . \ EXR$$

$$TRII_{ii'} = shii_{ii'} . \ \left(1 - mps_{i'}\right) . \ \left(1 - tins_{i'}\right) . \ YI_{i'}$$

$$EH_h = (1 - \textstyle\sum_{i\, \epsilon\, INSDNG} shii_{i\,h}) . \ (1 - mps_h) . \ (1 - tins_h) . \ YI_h$$

$$PQ_c . \ QH_{c\,h} = PQ_c . \ \gamma_{ch}^m + \beta_{ch}^m . (EH_h - \textstyle\sum_{c' \epsilon C} PQ_{c'} . \ \gamma_{c'h}^m)$$

$$QINV_c = IADJ . \ qinv_c$$

$$EG = \textstyle\sum_{c \epsilon C} PQ_c . \ qg_c + \sum_{i\, \epsilon\, INSDNG} trnsfr_{i\,gov} . \ cpi$$

$$YG = \textstyle\sum_{i\, \epsilon\, INSDNG} tins_i . \ YI_i + \sum_{c\, \epsilon CMNR} tm_c . \ pwm_c . \ QM_c . \ EXR + \sum_{c\, \epsilon\, C} tq_c . \ PQ_c . \ QQ_c +$$

$$\textstyle\sum_{f\, \epsilon\, F} YF_{gov\,f} + trnsfr_{gov\ row} . EXR$$

System constraints and macroeconomic closures

$$QQ_c = \textstyle\sum_{a\, \epsilon A} QINTA_{c\,a} + \sum_{h\, \epsilon\, H} QH_{c\,h} + qg_c + qdst_c$$

$$\textstyle\sum_{a\, \epsilon\, A} QF_{f\,a} = QFS_f$$

$$YG = EG + GSAV$$

$$\sum_{r\ c\ \epsilon\ CMNR} pwm_{cr} . \ QM_{cr} = \sum_{r\ c\ \epsilon\ CENR} pwe_{cr} . \ QE_{cr} +$$

$\sum_{i \in INSD} trnsfr_{i\,row} \,.\, fsav$

$$\sum_{i \in INSDNG} mps_i \,.\, (1 - \overline{tins_i}) \,.\, YI_i + GSAV + EXR \,.\, fsav = \sum_{c \in C} PQ_c \,.QINV_c$$

$+ \sum_{c \in C} PQ_c \,.qdst_c$

Factor accumulation and allocation equations

$AWF^{a}_{f\,t} = \sum_a \left[\left(\frac{QF_{f\,at}}{\sum_{a'} QF_{fa't}} \right) .\ WF_{f\,t} \,.\, wfdist_{f\,at} \right]$

$\eta^{a}_{f\,at} = \left(\frac{QF_{f\,at}}{\sum_{a'} QF_{fa't}} \right) .\ (\beta^a \,.\, \left[\frac{WF_{f\,t} \,.\, wfdist_{f\,at}}{AWF^{a}_{f\,t}} - 1 \right] + 1)$

$\Delta K^{a}_{f\,at} = \eta^{a}_{f\,at} \,.\, \left(\frac{\sum_c PQ_{c\,t} \,.\, qinv_{ct}}{PK_{f\,t}} \right)$

$PK_{ft} = \sum_c PQ_{ct} \,.\, \frac{qinv_{ct}}{\sum_{c'} qinv_{c't}}$

$QF_{f\,at+1} = QF_{f\,at} \,.\, (1 + \frac{\Delta K^{a}_{f\,at}}{QF_{f\,at}} - v_f)$

$QFS_{f\,1+1} = QFS_{f\,t} \,.\, (1 + \frac{\sum_a K_{f\,at}}{QFS_{f\,t}} - v_f)$

Appendix 2 – B

Variables

Ci	Final demand for private consumption	Mi	Imports
Di	Domestic sales of domestic output	P_i^m	Domestic price of imports
DST_i	Inventory investment by sector	P_i^e	Domestic price of exports
DK_i	Investment by sector of destination	PW_i^e	World price of exports
$DEPREC$	Total depreciation charges	P_i^q	Price of composite good
Ei	Exports	P_i^d	Domestic sales price
$EXPSUB$	Total export subsidies	P_i^x	Output price
INV	Fixed capital investment	P_i^k	Price of a unit of cap/sector
$FSAV$	Foreign savings	P_i^v	Value added price
$FDSC_{if}$	Factor demand	$PINDEX$	GDP deflator
$GDPVA$	Nominal GDP in market prices	Qi	Composite goods supply
G_i	Government final demand	R	Exchange rate
GR	Total government revenue	$RGDP$	Real GDP
$GOVSAV$	Government savings	$SAVING$	Total savings
$HHTAX$	Household tax revenue	$TARIFF$	Tariff revenue
$HHSAV$	Total household savings	WF_f	Average factor price
$INDTAX$	Total indirect tax revenue	X_i	Domestic output
$INVEST$	Total investment	Y_f^F	Factor income
INT_i	Intermediate input demand	Y_h^H	Household income
ID_i	Final demand for investment goods		

Appendix 2 – C

Parameters

a_{ij}	Input-output coefficients	$pwse_i$	World price of export substitutes
a_i^C	CES function shift parameter	t_h^H	Household income tax rate
a_i^D	Production function shift parameter	t_i^e	Export subsidy rates
a_i^T	CET function shift parameter	t_i^m	Tariff rate on imports
$alpha_{if}$	Production function share parameter	t_i^x	Indirect tax rate
b_{ij}	Capital composition matrix	$wfdist_{if}$	Factor mkt distortion parameters
$dstr_i$	Inventory investment ratio	α_{ij}	Production function exponents
$depr^i$	Depreciation rate	β_i^G	Government expenditure shares
$econ_i$	Export demand shift parameter	β_{ih}^H	Household expenditure shares
fs_f	Aggregate factor supply	δ_i	CES function share parameter
$gdtot$	Real government consumption	η_i	Export demand price elasticity
$kshr_i$	Investment destination shares	γ_i	CET function share parameter
mps_h	Household saving rates	ρ_i^C	CES function exponent
pw_i^m	World price of imports	ρ_i^T	CET function exponent

Appendix 3-A

Disaggregated Updated 2005 Ghana Social Accounting Matrix (Billion Cedis)

Production Quantities

Production levels (quantities)			
	Mt	ha	mt / ha
	Prod	area	Yield
amaiz1	151,892	79,762	1.9
arice1	18,166	7,864	2.3
asorg1	409	414	1.0
aogrn1	0	0	0.0
acass1	325,794	25,562	12.7
ayams1	121,119	15,992	7.6
acyam1	72,325	13,293	5.4
acpea1	454	454	1.0
asbea1	0	0	0.0
apoil1	50,901	161,751	0.3
agnut1	2,752	2,970	1.0
aonut1	44,893	55,456	0.8
afrud1	54,322	16,691	3.3
afrue1	134,497	21,219	6.3
avegd1	201,566	45,731	4.4
avege1	28,439	4,187	6.8
aplan1	348,404	22,718	15.3
acoco1	18,889	36,872	0.5
asugr1	0	0	0.0
aocro1	9,604	12,451	0.8
aoexp1	8,722	7,420	1.2
amaiz2	488,569	334,129	1.5
arice2	77,243	35,795	2.2
asorg2	1,437	1,456	1.0
aogrn2	0	0	0.0
acass2	2,571,923	175,226	14.7
ayams2	1,020,696	99,754	10.2
acyam2	1,087,662	142,267	7.6
acpea2	9,097	9,097	1.0
asbea2	1,350	1,432	0.9
apoil2	210,991	670,484	0.3

agnut2	37,105	40,040	1.0
aonut2	153,773	189,954	0.8
afrud2	230,085	70,696	3.3
afrue2	194,226	30,642	6.3
avegd2	530,379	120,332	4.4
avege2	1,497	220	6.8
aplan2	1,914,948	192,811	9.9
acoco2	497,285	970,710	0.5
asugr2	0	0	0.0
aocro2	25,429	32,966	0.8
aoexp2	12,795	12,094	1.1
amaiz3	600,026	278,700	2.2
arice3	28,306	19,278	1.5
asorg3	48,815	45,944	1.1
aogrn3	0	0	0.0
acass3	5,112,823	289,660	17.7
ayams3	1,797,306	122,022	14.7
acyam3	331,994	46,541	7.1
acpea3	10,000	10,000	1.0
asbea3	3,150	3,341	0.9
apoil3	51,103	162,394	0.3
agnut3	11,009	11,879	1.0
aonut3	15,500	19,147	0.8
afrud3	53,315	16,382	3.3
afrue3	15,080	2,379	6.3
avegd3	859,712	195,051	4.4
avege3	0	0	0.0
aplan3	1,108,747	116,879	9.5
acoco3	205,642	401,418	0.5
asugr3	0	0	
aocro3	6,088	9,471	0.6
aoexp3	648	787	0.8
amaiz4	417,224	309,679	1.3
arice4	183,284	97,014	1.9
asorg4	439,338	481,644	0.9
aogrn4	0	0	0.0
acass4	1,556,459	133,229	11.7
ayams4	1,665,545	148,965	11.2
acyam4	47,646	6,679	7.1

acpea4	90,449	90,449	1.0
asbea4	40,500	42,955	0.9
apoil4	32,750	104,072	0.3
agnut4	261,457	282,136	1.0
aonut4	351,835	434,619	0.8
afrud4	45,278	13,912	3.3
afrue4	57,197	9,024	6.3
avegd4	568,243	128,923	4.4
avege4	0	0	0.0
aplan4	199,865	21,974	9.1
acoco4	0	0	0.0
asugr4	0	0	0.0
aocro4	30,179	85,241	0.4
aoexp4	21,404	28,013	0.8

Appendix 3 – B

Labour Employment

Sectoral labor employment (QFBASE)				
Actual number of workers				
[Activities x Factors]	land1	land2	land3	land4
Amaiz	79762.35	334128.7	278700.1	309679
Arice	7863.942	35794.53	19278.41	97013.61
Asorg	414.226	1455.587	45943.89	481644
Aogrn	0	0	0	0
Acass	25561.54	175225.5	289660.4	133228.8
Ayams	15991.54	99754.36	122021.8	148964.8
Acyam	13293.13	142266.7	46541.12	6679.297
Acpea	307.0417	7092.14	9213.78	91671.24
Asbea	0	1431.818	3340.908	42954.53
Apoil	161751.3	670483.5	162394.2	104071.8
Agnut	2969.854	40040	11879.42	282136.1
Aonut	55455.62	189954.4	19147.06	434619.4
Afrud	16690.99	70695.99	16381.6	13912.29
Afrue	21218.82	30641.93	2379.088	9023.702
Avegd	45731.07	120332	195050.7	128922.6
Avege	4187.067	220.372	0	0
Aplan	22717.75	192811	116878.7	21973.54
Acoco	36871.65	970710	401418.4	0
Asugr	0	0	0	0
Aocro	12450.94	32966.02	9471.219	85240.97
Aoexp	7419.65	12094.44	787.4984	28013.06

Appendix 3 – C

Labour Wages

Sectoral labor wages (WFBASE)						
Unit: 1000 cedis per year						
[Activities x Factors]	labself1	labself2	labself3	labself4	labskll	labunsk
Amaiz	6835	6835	6835	6835	11099	5331
Arice	6835	6835	6835	6835	11099	5331
Asorg	6835	6835	6835	6835	11099	5331
Aogrn	6835	6835	6835	6835	11099	5331
Acass	6835	6835	6835	6835	11099	5331
Ayams	6835	6835	6835	6835	11099	5331
Acyam	6835	6835	6835	6835	11099	5331
Acpea	6835	6835	6835	6835	11099	5331
Asbea	6835	6835	6835	6835	11099	5331
Apoil	6835	6835	6835	6835	11099	5331
Agnut	6835	6835	6835	6835	11099	5331
Aonut	6835	6835	6835	6835	11099	5331
Afrud	6835	6835	6835	6835	11099	5331
Afrue	6835	6835	6835	6835	11099	5331
Avegd	6835	6835	6835	6835	11099	5331
Avege	6835	6835	6835	6835	11099	5331
Aplan	6835	6835	6835	6835	11099	5331
Acoco	6835	6835	6835	6835	11099	5331
Aocro	6835	6835	6835	6835	11099	5331
Aoexp	6835	6835	6835	6835	11099	5331
Achik	6835	6835	6835	6835	11099	5331
Aeggs	6835	6835	6835	6835	11099	5331
Abeef	6835	6835	6835	6835	11099	5331
Agoat	6835	6835	6835	6835	11099	5331
Aoliv	6835	6835	6835	6835	11099	5331
Afore	9070	9070	9070	9070	16282	10037
Afish	10435	10435	10435	10435	29768	15710
Amine					25385	14037
Aforf	3598	3598	3598	3598	20434	10572
Alocf	3598	3598	3598	3598	20434	10572
Acopr	3598	3598	3598	3598	20434	10572
Adair	3598	3598	3598	3598	20434	10572

Ameat	3598	3598	3598	3598	20434	10572
Atext						5461
Aclth					6400	4577
Afoot						8481
Awood						9122
Apapr					17142	10189
Aoils						30880
Apetr						30880
Adies						30880
Afuel						6063
Afert					15750	14184
Achem					8000	7257
Ametl						7403
Acapt	5547	5547	5547	5547	43490	8305
Acons					19095	10243
Awatr					30071	5454
Aelec					39159	11341
Atrad	5365	5365	5365	5365	11752	8787
Aosrv					41073	22978
Atran					32938	7435
Acomm					12190	8690
Abusi					31008	16163
Areal						10897
Acsrv	5601	5601	5601	5601	17477	6399
Aadmn					29969	10129
Aeduc					17049	11029
Aheal					17296	10541

Appendix 3 – D

Active Population (Actual Numbers)

Household	survey
Haccra	2,544,225
Hcurb	956,375
Hfurb	1,872,798
Hssub	2,060,706
Hsnub	683,302
Hcrur	1,498,344
Hfrur	3,821,583
Hssru	4,420,457
Hsnru	3,742,210

Appendix 3 – E

Institutions Group

	Gov	dtax	Stax	mtax	Etax	s-i	row
ccass							25
cyams							103
ccyam							
ccpea							
csbea							
cpoil							326
cgnut							71
conut							216
cfrud							
cfrue							297
cvegd							
cvege							100
cplan							
ccoco							7,672
cocro							
coexp							186
cchik							
ceggs							
cbeef							
cgoat							
coliv							
cfore							5,914
cfish							956
cmine							7,400
cforf							
clocf							

ccopr								931
cdair								
cmeat								773
ctext								55
cclth								14
cfoot								7
cwood								1,792
cpapr								1
coils								
cpetr								
cdies								
cfuel								
cfert								
cchem								54
cmetl							312	
ccapt							15,004	822
ccons							12,890	
cwatr								
celec								
ctrad								
cosrv								7,380
ctran								
ccomm								
cbusi								
creal								
ccsrv								
cadmn	12,326							
ceduc	2,633							
cheal	514							
trc								

labself1							
labself2							
labself3							
labself4							
labunsk							
labskll							
capa							
capn							
land1							
land2							
land3							
land4							
haccra	928						484
hcurb	471						137
hfurb	294						827
hssub	734						133
hsnub	49						17
hcrur	109						69
hfrur	464						159
hssru	1,673						175
hsnru	37						7
gov		7,293	10,304	3,524	1,089		5,714
dtax							
stax							
mtax							
etax							
s-i	6,776						18,062
row	915						

Appendix 3 – F

Household Demand Elasticities - Linear Expenditure System (LES) Demand

(Households x Commodities)	hhd	haccra	hcurb	Hfurb	hssub	Hsnub	Hcrur	hfrur	hssru	hsnru
Cocoa Beans	0.955733	0.699767	0.6997665	0.699767	0.699767	1.249521	1.249521	1.249521	1.249521	1.249521
Forestry	1.395631	1.068427	1.068427	1.068427	1.068427	1.395631	1.395631	1.395631	1.395631	1.395631
Fisheries	1.395631	1.068427	1.068427	1.068427	1.068427	1.395631	1.395631	1.395631	1.395631	1.395631
Mining	1.116794	1.116794	1.116794	1.116794	1.116794	1.03263	1.03263	1.03263	1.03263	1.03263
Petroleum	2.931373	3.109394	3.109394	3.109394	3.109394	2.198208	2.198208	2.198208	2.198208	2.198208
Construction	1.840823	1.840823	1.840823	1.840823	1.840823	1.965889	1.965889	1.965889	1.965889	1.965889
Water	1.840823	1.840823	1.840823	1.840823	1.840823	1.965889	1.965889	1.965889	1.965889	1.965889
Electricity	1.840823	1.840823	1.840823	1.840823	1.840823	1.965889	1.965889	1.965889	1.965889	1.965889
Trade	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589
Communication	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589	1.064589
Public admin	1.113446	1.115441	1.115441	1.115441	1.115441	1.000976	1.000976	1.000976	1.000976	1.000976
Education	1.113446	1.115441	1.115441	1.115441	1.115441	1.000976	1.000976	1.000976	1.000976	1.000976
Health	1.113446	1.115441	1.115441	1.115441	1.115441	1.000976	1.000976	1.000976	1.000976	1.000976

Appendix 3 – G

Trade and Production Elasticities

Trade Elasticities (TRADELAS)			**Production Elasticities (PRODELAS)**		
Subsectors	***Armington***	***Transformation***	**Subsectors**	***Factor substitution***	
	SIGMAQ	**SIGMAT**		**PRODELAS**	**PRODELAS2**
Cocoa Beans	6.5	4.0	All sectors/subsectors	0.75	1.20
Forestry	5.0	4.0			
Fishing	2.5	4.0			
Mining	6.0	4.0			
Petroleum	10.4	4.0			
Construction	6.0	4.0			
Water	6.0	4.0			
Electricity	6.0	4.0			
Trade	4.0	4.0			
Communication	4.0	4.0			
administration	4.0	4.0			
Education	4.0	4.0			
Health	4.0	4.0			

Appendix 3 – H

Set Definitions

Activities and Commodities		
amaiz	Cmaiz	Maize
arice	Crice	Rice
asorg	Csorg	Sorghum and millet
aogrn	Cogrn	Other cereals
acass	Ccass	Cassava
ayams	Ayams	Yams
acyam	Ccyam	Cocoyams
acpea	Ccpea	Cowpea
asbea	Csbea	Soyabean
apoil	Cpoil	Palm oil
agnut	Cgnut	Groundnuts
aonut	Conut	Tree nuts
afrud	Cfrud	Fruit (domestic)
afrue	Cfrue	Fruit (export)
avegd	Cvegd	Vegetables (domestic)
avege	Cvege	Vegetables (export)
aplan	Cplan	Plantains
acoco	Ccoco	Cocoa beans
asugr	Csugr	Sugarcane
aocro	Cocro	Other crops
aoexp	Coexp	Export industrial crops
achik	Cchik	Chicken broiler (mostly imported)
aeggs	Ceggs	Eggs and layers (domestic)
abeef	Cbeef	Beef
agoat	Cgoat	Sheep and goat meat
aoliv	Coliv	Other meats

afore	Cfore	Forestry
afish	Cfish	Fishing
agold	Cgold	Gold
aomin	Comin	Other mining
aforf	Cforf	Other formal food processing
alocf	Clocf	Informal food processing
acopr	Ccopr	Cocoa processing
asupr	Csupr	Sugar
adair	Cdair	Dairy products
ameat	Cmeat	Meat and fish processing
atext	Ctext	Textiles
aclth	Cclth	Clothing
afoot	Cfoot	Leather and footwear
awood	Cwood	Wood products
apapr	Cpapr	Paper products, publishing and printing
aoils	Coils	Crude and other oils
apetr	Cpetr	Petroleum
adies	Cdies	Diesel
afuel	Cfuel	Other fuels
afert	Cfert	Fertilizer
achem	Cchem	Other Chemicals
arubb	Crubb	Rubber products?
anmet	Cnmet	Non-metallic mineral products
ametl	Cmetl	Metal products
amach	Cmach	Non-electrical machines
aemch	Cemch	Electrical machines
atele	Ctele	Radio and television equipment
amedi	Cmedi	Medical and optical equipment
avehi	Cvehi	Motor vehicles
avehp	Cvehp	Motor vehicles parts

atequ	Ctequ	Other transport equipment
aoman	Coman	Other manufactured products
acons	Ccons	Construction
awatr	Cwatr	Water
aelec	Celec	Electricity
agasp	Cgasp	Gas
atrad	Ctrad	Trade services
aosrv	Cosrv	Repairing, hotel, and restruant
atran	Ctran	Transport services
acomm	Ccomm	Communication
aban	Cbusi	Banking and business services
arees	Creal	Real estate
acsrv	Ccsrv	Community and other services
aadmn	Cadmn	Public administration
aeduc	Ceduc	Education
aheal	Cheal	Health
Regions		
coast	Coastal zone	
forest	Forest zone	
south	Southern Savanah zone	
north	Northern Savanah zone	
accra	Greater Accra Metropolitan Area	
Factors		
labself	Self-employed labor (agriculture)	
labelem	Elementary labor (agriculture and non-agriculture)	
labskll	Skilled labor (non-agriculture)	
labunsk	Unskilled labor (non-agriculture)	
cap	Capital	

land1	Land (coast)
land2	Land (forest)
land3	Land (south)
land4	Land (north)
Other accounts	
ent	Enterprises
gov	Government
dtax	Direct taxes
stax	Sales taxes
mtax	Import tariffs
etax	Export taxes
s-i	Savings-investment
row	Rest of world

Appendix 4 – A

GAMS Code for Base Model

GAMS Rev 228 x86/MS Windows
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Input file: 1dmodel.gms. IFPRI Extended standard recursive dynamic CGE modeling system, Version 2.00

```
*$OFFSYMLIST OFFSYMXREF
*The dollar control option makes empty data initialization statements
*permissible (e.g. sets without elements or parameters without data)



*----------------------------------------------------------------------
*1. SET DECLARATIONS ---------------------------------------------------
*----------------------------------------------------------------------

In this section, all sets are declared. They are divided into the
following groups:
a. model sets (appearing in the model equations)
b. calibration sets (used to initialize variables and define model
   parameters)
c. report sets (used in report files)

SETS
*a. model sets
AC          global set for model accounts - aggregated microsam accounts
ACNT(AC)    all elements in AC except TOTAL
AAG(AC)     aggregate activity accounts
R(AC)       trading regions
A(AC)       activities
ACES(A)     activities with CES fn at top of technology nest
ALEO(A)     activities with Leontief fn at top of technology nest
C(AC)       commodities
CD(C)       commodities with domestic sales of output
CDN(C)      commodities without domestic sales of output
CE(C)       exported commodities
CER(C,R)    imported commodities by region
CEN(C)      non-export commodities
CM(C)       imported commodities
CMR(C,R)    imported commodities by region
CMN(C)      non-imported commodities
CX(C)       commodities with output
F(AC)       factors
FAGG(F)     aggregate factors in factor nesting
```

```
FLAB(F)      labor
FLND(F)      land
FCAP(F)      capital
FECW(F)      economywide factor
FLOC(F)      economywide factor
FDIS(F)      disaggregate factors
FNEST(F,F)   nested structure of factors
FTREE(F,F,F) nested structure of factors
GOVF         government functions for expenditure
MFA1(F,A)    factor F (agg or disagg) is used by A at top of nest
MFA2(F,F,A)  factor FP is aggregated to factor F for activity A
INS(AC)      institutions
INSD(INS)    domestic institutions
INSDNG(INSD) domestic non-government institutions
EN(INSDNG)   enterprises
H(INSDNG)    households
HAGG(H)      aggregate households
*b. calibration sets
CINV(C)      fixed investment goods
CT(C)        transaction service commodities
CTD(AC)      domestic transactions cost account
CTE(AC)      export transactions cost account
CTM(AC)      import transactions cost account
*c. report sets
AAGR(A)      agricultural activities
AMIN(A)      mining activities
AIND(A)      industrial activities
ASER(A)      service activities
ANAGR(A)     non-agricultural activities
CAGR(C)      agricultural commodities
CMIN(C)      mining commodities
CIND(C)      industrial commodities
CSER(C)      service commodities
CNAGR(C)     non-agricultural commodities
HURB(H)      urban households
HRUR(H)      rural households
HURB2(H)
HRUR2(H)

*d. mappings
ZONE
MAPAAGA(AAG,A) aggregate activities to region-specific activities
MAPA2C(AAG,C)  direct mapping between activities and commodities
MAPAZONE(A,ZONE)
;
```

```
*ALIAS statement to create identical cets
ALIAS
 (AC,ACP)   , (ACNT,ACNTP), (A,AP,APP), (AAG,AAGP), (ZONE,ZONEP)
 (C,CP,CPP) , (CE,CEP)    , (CM,CMP)
 (F,FP,FPP) , (FAGG,FAGGP), (FLAB,FLABP), (FCAP,FCAPP),  (FLND,FLNDP), (FE
CW,FECWP),  (FLOC,FLOCP)
 (GOVF,GOVFP),(INS,INSP) ,  (INSD,INSDP), (INSDNG,INSDNGP), (H,HP), (R,RP)
;

*-----------------------------------------------------------------------
*2. DATABASE ------------------------------------------------------------
*-----------------------------------------------------------------------

PARAMETER
 SAM(AC,ACP)     standard SAM
 NEST(F,FP)      nested structure of factors in the model
 TREE(F,FP)      direct and indirect factor mapping in nested factor structure
 SAMBALCHK(AC)   column minus row total for SAM
;

*INCLUDE ONE COUNTRY DATA SET
*Remove asterisk in front of ONE (AND ONLY ONE) of the following lines
*or add a new line for new file with country data

INCLUDE    C:\Users\camara\Desktop\2011 Desktop\CAADP model3\1MODEL.DAT

GAMS Rev 228  x86/MS Windows
Input file: 1dmodel.dat. IFPRI Extended standard recursive dynamic CGE modeling system,
Version 2.00
Input file: 1dmodel.gms. IFPRI Extended standard recursive dynamic CGE modeling system,
Version 2.00

   Version 2.00 Release date: July 2005
   Last update:

   This file includes country-specific model data.
   Signals to the user who is constructing his/her own data set:
   "!!" -- read carefully; perhaps need to supply information

   The file is divided into the following searchable blocks:
   1. SET DEFINITIONS
   2. SAM
   3. ELASTICITIES
   4. PHYSICAL FACTOR QUANTITIES
   5. COMMODITY VALUE SHARES FOR HOME CONSUMPTION
   6. INITIALIZATION OF TAX DATA
```

```
SCALAR
 AGGREGATE      aggregate households (0 for no - 1 for yes)      / 0 /
 KOPTION        capital updating options (1 DDM 2 XD)           / 2 /
;

*------------------------------------------------------------------------
*1. SET DEFINITIONS -----------------------------------------------------
*------------------------------------------------------------------------

*Read in set definitions from Excel file (1data.xls) --------------

*Model data (full set of activities and households)
GDXIN   C:\Users\camara\Desktop\2011 Desktop\CAADP model3\1model.gdx

*Load sets
--- LOAD  AC = 1:AC
--- LOAD  AAG = 2:AAG
--- LOAD  A = 3:A
--- LOAD  AAGR = 4:AAGR
--- LOAD  AMIN = 5:AMIN
--- LOAD  AIND = 6:AIND
--- LOAD  ASER = 7:ASER
--- LOAD  MAPAAGA = 31:MAPAAGA
--- LOAD  C = 8:C
--- LOAD  CAGR = 9:CAGR
--- LOAD  CMIN = 10:CMIN
--- LOAD  CIND = 11:CIND
--- LOAD  CSER = 12:CSER
--- LOAD  F = 13:F
--- LOAD  FAGG = 14:FAGG
--- LOAD  FLAB = 15:FLAB
--- LOAD  FCAP = 16:FCAP
--- LOAD  FLND = 17:FLND
--- LOAD  FECW = 18:FECW
--- LOAD  FLOC = 19:FLOC
--- LOAD  GOVF = 33:GOVF
--- LOAD  INS = 20:INS
--- LOAD  INSD = 21:INSD
--- LOAD  INSDNG = 22:INSDNG
--- LOAD  EN = 23:EN
--- LOAD  H = 24:H
--- LOAD  HURB = 25:HURB
--- LOAD  HRUR = 26:HRUR
--- LOAD  CTD = 27:CTD
```

```
--- LOAD  CTE = 28:CTE
--- LOAD  CTM = 29:CTM
--- LOAD  R = 30:R
--- LOAD  NEST = 51:NEST
--- LOAD  MAPA2C = 32:MAPA2C
--- LOAD  ZONE = 34:ZONE
--- LOAD  MAPAZONE = 35:MAPAZONE

*Ghana with CES function at the top of the technology nest
 ACES(A)               = NO;
 ALEO(A)$(NOT ACES(A))  = YES;
 ANAGR(A)              = NOT AAGR(A);
 CNAGR(C)              = NOT CAGR(C);
 HAGG('HHD')           = YES;
 ACNT(AC)              = YES;
 ACNT('TOTAL')         = NO;
 ACNT('HID')           = NO;
 ACNT('H')             = NO;
 ACNT('HSIZE')         = NO;
 ACNT('WEIGHT')        = NO;

*XD 2007Dec
 HURB2(H)              = NO;
 HURB2(H)$HURB(H)      = YES;
 HURB2('hhd')          = NO;
 HURB2('haccra')       = NO;
 HRUR2(H)              = NO;
 HRUR2(H)$HRUR(H)      = YES;

*Add additional sets used in this country's data calibration
*e.g. sets used in the mapping between factor nests



*-----------------------------------------------------------------------
*2. SAM ------------------------------------------------------------------------------------
*-----------------------------------------------------------------------

PARAMETER
 SAM1(AC,ACP)
 SAM2(AC,ACP)
 SAM3(AC,ACP)
 SAM4(AC,ACP)
 SAM5(AC,ACP)
 GOVFSHR(C,GOVF)        government expenditure share by commodity and function
```

```
;

*Load Social Accounting Matrix (SAM)
--- LOAD  SAM1 = 36:SAM1
--- LOAD  SAM2 = 37:SAM2
--- LOAD  SAM3 = 38:SAM3
--- LOAD  SAM4 = 39:SAM4
--- LOAD  SAM5 = 40:SAM5
--- LOAD  GOVFSHR = 52:GOVFSHR

*Loading large SAM sections into single SAM parameter
 SAM(AC,ACP) = SAM1(AC,ACP);
 SAM(AC,ACP) = SAM(AC,ACP) + SAM2(AC,ACP);
 SAM(AC,ACP) = SAM(AC,ACP) + SAM3(AC,ACP);
 SAM(AC,ACP) = SAM(AC,ACP) + SAM4(AC,ACP);
 SAM(AC,ACP) = SAM(AC,ACP) + SAM5(AC,ACP);

*Identify government spending patterns by functions
 GOVFSHR(C,GOVF)$SUM(GOVFP, GOVFSHR(C,GOVFP)) = GOVFSHR(C,GOVF) /
SUM(GOVF
     P, GOVFSHR(C,GOVFP));
 GOVFSHR(C,GOVF)$((ORD(GOVF) EQ 1) AND (SUM(GOVFP,
GOVFSHR(C,GOVFP)) EQ 0)
     ) = 1;

*The following adjustments are only relevant to a specific country SAM ---

SET
 REMEXP(C)       remove exports with small shares
         / ccass, cclth, cfoot, cpapr, cmetl /
 REMIMP(C)       remove imports with small shares
         /   /
 REEXPORT(C)     remove imports with re-export problem
         /   /
;

*coils, ,

*XD 2007Dec
*Adjust factor income distribution such that urban households do not share
      family labor income
Parameter
AdjSAM(INSD,F)
;

AdjSAM('hcrur','labself1') = SAM('hcrur','labself1') + SAM('hcurb','labsel
```

```
f1') ;
AdjSAM('hfrur','labself2') = SAM('hfrur','labself2') + SAM('hfurb','labself2') ;
AdjSAM('hssru','labself3') = SAM('hssru','labself3') + SAM('hssub','labself3') ;
AdjSAM('hsnru','labself4') = SAM('hsnru','labself4') + SAM('hsnub','labself4') ;

AdjSAM('hcrur','labunsk') = SAM('hcrur','labunsk') - SAM('hcurb','labself1') ;
AdjSAM('hfrur','labunsk') = SAM('hfrur','labunsk') - SAM('hfurb','labself2') ;
AdjSAM('hssru','labunsk') = SAM('hssru','labunsk') - SAM('hssub','labself3') ;
AdjSAM('hsnru','labunsk') = SAM('hsnru','labunsk') - SAM('hsnub','labself4') ;

AdjSAM('hfrur','labunsk') = AdjSAM('hfrur','labunsk') + 450 ;
AdjSAM('hcrur','labunsk') = AdjSAM('hcrur','labunsk') + 300 ;

AdjSAM('hssru','labunsk') = AdjSAM('hssru','labunsk') - 500 ;
AdjSAM('hsnru','labunsk') = AdjSAM('hsnru','labunsk') - 250 ;
AdjSAM('hfrur','capn')    = SAM('hfrur','capn') - 450 ;
AdjSAM('hcrur','capn')    = SAM('hcrur','capn') - 300 ;
AdjSAM('hssru','capn')    = SAM('hssru','capn') + 500 ;
AdjSAM('hsnru','capn')    = SAM('hsnru','capn') + 250 ;

AdjSAM('hcurb','labunsk') = SAM('hcurb','labunsk') + SAM('hcurb','labself1') ;
AdjSAM('hfurb','labunsk') = SAM('hfurb','labunsk') + SAM('hfurb','labself2') ;
AdjSAM('hssub','labunsk') = SAM('hssub','labunsk') + SAM('hssub','labself3') ;
AdjSAM('hsnub','labunsk') = SAM('hsnub','labunsk') + SAM('hsnub','labself4') ;

AdjSAM('hcrur','labskll') = SAM('hcrur','labskll') + 350 ;
AdjSAM('hcrur','labunsk') = AdjSAM('hcrur','labunsk') - 350 ;

AdjSAM('hfurb','labskll') = SAM('hfurb','labskll') - 350 ;
AdjSAM('hfurb','labunsk') = AdjSAM('hfurb','labunsk') + 350 ;

AdjSAM('hfrur','labunsk') = AdjSAM('hfrur','labunsk') + 350 ;
AdjSAM('hfrur','labskll') = SAM('hfrur','labskll') - 350 ;

AdjSAM('hfurb','labunsk') = AdjSAM('hfurb','labunsk') - 350 ;
```

```
AdjSAM('hfurb','labskll') = AdjSAM('hfurb','labskll') + 350 ;

SAM(HRUR2,FLAB)$AdjSAM(HRUR2,FLAB) = AdjSAM(HRUR2,FLAB) ;
SAM(HURB2,FLAB)$AdjSAM(HURB2,FLAB) = AdjSAM(HURB2,FLAB) ;

SAM(HRUR2,'capn')$AdjSAM(HRUR2,'capn') = AdjSAM(HRUR2,'capn') ;

SAM('hcurb','labself1') = 0 ;
SAM('hfurb','labself2') = 0 ;
SAM('hssub','labself3') = 0 ;
SAM('hsnub','labself4') = 0 ;

*Move exports to changes in inventories
 SAM(REMEXP,'DSTK') = SAM(REMEXP,'DSTK') + SAM(REMEXP,'ROW');
 SAM('DSTK','S-I')  = SAM('DSTK','S-I') + SUM(REMEXP, SAM(REMEXP,'ROW'));
 SAM('S-I','ROW')   = SAM('S-I','ROW') + SUM(REMEXP, SAM(REMEXP,'ROW'));
 SAM(REMEXP,'ROW')  = 0;
*Move imports to changes in inventories
 SAM('ROW',REMIMP) = SAM('ROW',REMIMP) + SAM('MTAX',REMIMP);
 SAM('MTAX',REMIMP) = 0;
 SAM(REMIMP,'DSTK') = SAM(REMIMP,'DSTK') - SAM('ROW',REMIMP);
 SAM('DSTK','S-I')  = SAM('DSTK','S-I') - SUM(REMIMP, SAM('ROW',REMIMP));
 SAM('S-I','ROW')   = SAM('S-I','ROW') - SUM(REMIMP, SAM('ROW',REMIMP));
 SAM('ROW',REMIMP)  = 0;
 SAM('GOV','MTAX')  = SUM(C, SAM('MTAX',C));
 SAM('ROW','GOV')   = 0;
 SAM('ROW','GOV')   = SUM(ACNT, SAM(ACNT,'ROW')-SAM('ROW',ACNT));
*Move trade transactions costs to domestic costs
 SAM(CTD,REMEXP) = SAM(CTD,REMEXP) + SUM(CTE, SAM(CTE,REMEXP));
 SAM(CTD,REMIMP) = SAM(CTD,REMIMP) + SUM(CTM, SAM(CTM,REMIMP));
 SAM(CTE,REMEXP) = 0;
 SAM(CTM,REMIMP) = 0;
 SAM(C,CTM)$SUM(CP, SAM(CP,CTM)) = SAM(C,CTM)/SUM(CP, SAM(CP,CTM)) * SUM(ACNT, SAM(CTM,ACNT));
 SAM(C,CTD)$SUM(CP, SAM(CP,CTD)) = SAM(C,CTD)/SUM(CP, SAM(CP,CTD)) * SUM(ACNT, SAM(CTD,ACNT));
 SAM(C,CTE)$SUM(CP, SAM(CP,CTE)) = SAM(C,CTE)/SUM(CP, SAM(CP,CTE)) * SUM(ACNT, SAM(CTE,ACNT));
*Move import tariffs to sales taxes
 SAM('STAX',REMIMP) = SAM('STAX',REMIMP) + SAM('MTAX',REMIMP);
```

```
 SAM('MTAX',REMIMP) = 0;
 SAM('GOV','STAX')    = SUM(ACNT, SAM('STAX',ACNT));
 SAM('GOV','DTAX')    = SUM(ACNT, SAM('DTAX',ACNT));
*Remove any small imbalances that remain
 SAM(C,'DSTK') = SUM(ACNT, SAM(ACNT,C) - SAM(C,ACNT)) + SAM(C,'DSTK');
 SAM('DSTK','S-I') = SUM(ACNT, SAM(ACNT,'DSTK'));
 SAM('S-I','ROW') = SAM('S-I','ROW') + SUM(ACNT, SAM(ACNT,'S-I')-SAM('S-I',ACNT));
*If aggregate switch is chosen then group all households together into one category (HHD)
IF (AGGREGATE EQ 1,
*Aggregate existing households into HHD
 SAM('HHD',ACNT) = SUM(H$(NOT HAGG(H)), SAM(H,ACNT));
 SAM(ACNT,'HHD') = SUM(H$(NOT HAGG(H)), SAM(ACNT,H));
*Clear existing household accounts H
 SAM(H,AC)$(NOT HAGG(H)) = 0;
 SAM(AC,H)$(NOT HAGG(H)) = 0;
);
*Remove re-exports from SAM (eliminates exports by reducing imports)
 SAM('ROW',REEXPORT) = SAM('ROW',REEXPORT) - SAM(REEXPORT,'ROW') + SUM(A, SAM(A,REEXPORT));
 SAM(REEXPORT,'ROW') = SUM(A, SAM(A,REEXPORT));
*Aggregate agriculture and non-agriculture capital
SAM('CAPN',ACNT) = SAM('CAPA',ACNT)+SAM('CAPN',ACNT);
SAM(ACNT,'CAPN') = SAM(ACNT,'CAPA')+SAM(ACNT,'CAPN');
SAM('CAPA',ACNT) = 0;
SAM(ACNT,'CAPA') = 0;
*------------------------------------------------------------------------
*$INCLUDE 1SAMBAL.INC
*Account totals are recomputed. Check for SAM balance.
 SAM('TOTAL',AC) = 0;
 SAM(AC,'TOTAL') = 0;
 SAM('TOTAL',AC) = SUM(ACNT, SAM(ACNT,AC));
 SAM(AC,'TOTAL') = SUM(ACNT, SAM(AC,ACNT));
```

```
PARAMETER
 BALCHK(AC) column minus row total for SAM after running SAMBAL;

 BALCHK(AC)      = SAM('TOTAL',AC) - SAM(AC,'TOTAL');

 DISPLAY "After running SAMBAL", BALCHK;
 DISPLAY "After running SAMBAL", SAM;

*Billions of Ghanaian Cedis
PARAMETER
 SCALE          SCALING PARAMETER FOR SAM / 1 /;

 SAM(AC,ACP) =  SAM(AC,ACP) * SCALE;

*Defining CINV using SAM data with potential user input.

*All commodities receiving payments from S-I are included in the set CINV.
*Note: Negative payments are for stock changes and should be treated
*as such.
 CINV(C)$SAM(C,'S-I') = YES;

*!!- User option to exclude selected commodities from the set CINV. Only
*relevant for SAMs without the account DSTK.
*Example:
*If the set C includes a commodity called CWHEAT and payments in the cell
*SAM('CWHEAT','S-I') are for stock changes, the user should include
*the following line in the program:
* CINV('CWHEAT')  = NO;

DISPLAY CINV;

*----------------------------------------------------------------------
*3. ELASTICITIES -------------------------------------------------------
*----------------------------------------------------------------------

!!- In this section, the user inputs elasticities for trade, production,
and household consumption. If the user does not supply all required
data, missing data will be generated in STDMOD.GMS using simple
assumptions.


*Trade elasticities -----------------------------------------

*SIGMAQ is the elasticity of substitution between imports
*and domestic output in domestic demand.
*SIGMAT is the elasticity of transformation for domestic
```

```
*marketed output between exports and domestic supplies.

SET
 TRDELAS  trade elasticities
 /
 SIGMAQ  Armington elasticity
 SIGMAT  CET elasticity
 REGIMP  regional import substitution elasticity
 REGEXP  regional export substitution elasticity
 /

 PRDELAS  production elasticities
 /
 PRODELAS
 PRODELAS2
 /
;

PARAMETER
 TRADELAS(AC,TRDELAS)  Armington and CET elasticities by commodity
 PRODELAS(A)     Elas of substit bt. factors - bottom of technology nest
 PRODELASTAB(A,PRDELAS)
 PRODELAS2(A)    Elas of substit bt. agg fac & intermed - top of tech nest
 PRODELAS3(F,A)  Elasticity of substitution for higher layer factors
 ELASAC(C)       Output aggregation elasticity for commodity C
;

*Load trade elasticities
--- LOAD  TRADELAS = 41:TRADELAS
--- LOAD  PRODELASTAB = 42:PRODELASTAB

*Top-level elasticities
 PRODELAS(A)        = PRODELASTAB(A,'PRODELAS');
*Overwrite factor substitution to ensure exogenous sector growth rates
 PRODELAS2(A)       = PRODELASTAB(A,'PRODELAS2');
*Nested layer elasticities
 PRODELAS3(F,A)     = 1.2;
 PRODELAS3(FAGG,A)  = 1.5;

SET CNTRADE(C)   commodities with less flexible regional substitutbility /

/;

*Output aggregation function elasticity
 ELASAC(C)       = 8.0;
 ELASAC(CNTRADE) = 0.5;
```

```
*Nested factor demand mappings ------------------------------------------
*Calculate all direct and indirect nested factors beneath each aggregate factor
 TREE(F,FAGG)$(SMAX(FP, NEST(F,FP)) GT SMAX(FP, NEST(FP,FAGG))) = 1;
 TREE(F,FAGG)$(NEST(F,FAGG) EQ SMAX(FP, NEST(FP,FAGG))) = 1;
*Assign disaggregated factors to existing factors set
 FDIS(F)$SAM(F,'TOTAL') = YES;
 FNEST(F,FP)$NEST(FP,F) = YES;
 FTREE(F,FP,FPP)$(FDIS(FPP) AND TREE(FPP,FP) AND FNEST(F,FP)) = YES;
 FTREE(F,FP,FP)$(FDIS(FP) AND FNEST(F,FP)) = YES;
*set default to true if SAM is true
 MFA1(F,A)$SAM(F,A) = YES;
*set all nested factors to false
 MFA1(F,A)$SUM(FAGG, TREE(F,FAGG)) = NO;
*set active labor category for top layer
 MFA1(FAGG,A)$(SMAX(F, NEST(F,FAGG)) EQ 1) = YES;
*1st lower VA level (from top)
 MFA2(F,FP,A)$(FNEST(F,FP) AND SUM(FPP$(FTREE(F,FP,FPP) AND NOT
FAGG(FPP))
    , SAM(FPP,A))) = YES;
*Prevent nested functions for non-active activities
 MFA1(F,A)$(NOT SAM('TOTAL',A))    = NO;
 MFA2(F,FP,A)$(NOT SAM('TOTAL',A)) = NO;
 MFA1(FAGG,A)$(NOT SUM(FP, MFA2(FAGG,FP,A))) = NO;
DISPLAY MFA1, MFA2;
*Household population data -----------------------------------------
*Note: population data are not needed to run the model.
*However, they may be useful for verification of household
*model parameters and for report parameters.
PARAMETER
 POP(H)          Base-year population for household h (units)
 POPTAB(AC,*)
;
--- LOAD  POPTAB = 50:POPTAB
```

```
IF (AGGREGATE EQ 1,
 POPTAB('HHD','SURVEY') = SUM(H, POPTAB(H,'SURVEY'));
 POPTAB(H,'SURVEY')$(NOT H('HHD')) = 0;
);

 POP(H) =  POPTAB(H,'SURVEY');

*Household consumption elasticities -------------------------------
*Note: The Frisch parameter is included in this section.

PARAMETERS
 LESELAS1(H,C)    LES demand elasticities
 FRISCH(H)        Frisch parameter for household LES demand
 LESELAS2(A,C,H)  Exp'e elasticity of home dem by com - act - hhd
;

--- LOAD  LESELAS1 = 43:LESELAS1

IF (AGGREGATE EQ 1,
 LESELAS1('HHD',C) = 0.9;
 LESELAS1(H,C)$(NOT H('HHD')) = 0;
);

*If LES elasticity missing in data then assign default value
 LESELAS1(H,C)$(NOT LESELAS1(H,C)) = 0.9;

 LESELAS2(A,C,H) =  0.9;
 FRISCH(H)       = -1;

*-------------------------------------------------------------------------------------------
*4. PHYSICAL FACTOR QUANTITIES AND FACTOR MARKET STRUCTURES --------------
*-----------------------------------------------------------------------

PARAMETER
*initial employment numbers
 SWITCH            if using wage (1) employment (2) or SAM data (3) / 1 /
 SAMUNIT           SAM unit in relation to wage units              / 1000 /
 WAGEINFLATE       inflate wages to base year (ratio to one)        / 1 /
 QFBASE(F,A)       sectoral employment data
 WFBASE(F,A)       sectoral wage data
 QFINPUT(F,AAG)    sectoral employment data
 WFINPUT(F,AAG)    sectoral wage data
 QFSBASE(AC)       total employment data
 CHKWAGE(F,A)      check for missing wage data
```

```
 CHKEMP(F,*)        compare employment approach to wage approach
*capital initialisation
 GRSCAPINC          gross capital income
 CAPSTK             total capital stock
 ACOR(F)            average capital-output ratio
*factor adjustments and labor closures
 LABDIFFSCALE(F)    labor unit adjustment factor (to ensure working deltava)
 LABSCALE           labor unit                                 / 1 /
 etals(F)           elasticity of labor supply
 CONVERGE0(F)       wage convergence parameter
 CONVERGE(F)        wage convergence parameter
;
*While these adjustments must be removed when computing results from the model
*but the adjustments reduce the substantial differences in value-added shares
*between especially skilled and unskilled workers
 LABDIFFSCALE(F)     = 1;
--- LOAD  QFINPUT = 44:QFINPUT
--- LOAD  WFINPUT = 45:WFINPUT
 QFBASE(F,A) = SUM(AAG$MAPAAGA(AAG,A), QFINPUT(F,AAG));
 WFBASE(F,A) = SUM(AAG$MAPAAGA(AAG,A), WFINPUT(F,AAG))*WAGEINFLATE;
*Ghana: scale land units to 1000 ha
 QFBASE(FLND,A) = SUM(AAG$MAPAAGA(AAG,A), QFINPUT(FLND,AAG)) / 1000;
*Adjustment factors
 QFBASE(F,A)$(NOT SAM(F,A)) = 0;
 WFBASE(F,A)$(NOT SAM(F,A)) = 0;
*The following code uses the wage data to determine employment
IF (SWITCH EQ 1,
 CHKWAGE(FLAB,A)$(SAM(FLAB,A) AND (NOT WFBASE(FLAB,A))) = 1/0;
 CHKEMP(FLAB,'EMPLOY-APP') = SUM(A, QFBASE(FLAB,A));
 QFBASE(FLAB,A)$WFBASE(FLAB,A) = SAM(FLAB,A) * SAMUNIT / WFBASE(FLAB,A);
 CHKEMP(FLAB,'WAGE-APP') = SUM(A, QFBASE(FLAB,A));
 DISPLAY CHKWAGE, WFBASE, CHKEMP;
);
IF (SWITCH EQ 3,
 QFBASE(FLAB,A) = 0;
```

```
);
*Factor supply equals sum of factor employment
 QFBASE(FLAB,A) = QFBASE(FLAB,A) * LABSCALE * LABDIFFSCALE(FLAB);
*Capital/output ratio (actually capital/value-added ratio) = 2 in South Africa
 ACOR(FCAP)          =  4.0;
*Capital initialization
 GRSCAPINC(FCAP)                         = SAM(FCAP,'TOTAL');
 CAPSTK(FCAP)$SUM(A, QFBASE(FCAP,A))       = SUM(A, QFBASE(FCAP,A));
 CAPSTK(FCAP)$(NOT SUM(A, QFBASE(FCAP,A))) = ACOR(FCAP)*SAM(FCAP,'TOTAL');
 QFBASE(FCAP,A)$(NOT QFBASE(FCAP,A))       = CAPSTK(FCAP)*(SAM(FCAP,A)/GRSCAPINC(FCAP));
 QFSBASE(F) = SUM(A, QFBASE(F,A));
*Labor supply elasticities -----------------------------------------
*Add factors with flexible labor supply to the set FLS
*Set factor supply elasticity
SET
 FLS(F)          factors with flexible supply /
 /;
*Upward sloping supply curve not allowed for aggregate factors (automatic)
 FLS(F)$(NOT FLAB(F)) = NO;
DISPLAY FLS;
*Set factor supply elasticity
 etals(F)      = 1.2;
*Fixed relative wages ---------------------------------------------
SET
 LREL(F)       factor groups with fixed relative wages /
 /
*Flexible factors first, fixed factors in parentheses
 MAPRELW(F,FP) mapping between flexible and fixed factors /
 /;
*fixing relative wages is not allowed for aggregate factors
```

```
 LREL(FAGG)      = NO;
 LREL(FLS)       = NO;
*fixing relative wages is not allowed for aggregate factors
 MAPRELW(FAGG,F) = NO;
 MAPRELW(F,FAGG) = NO;

*Set convergence rate between flexible and fixed factors' real wages
*e.g. 0.01 is an annual 1 percent convergence
 CONVERGE0(F) = 0.00;
 CONVERGE(F)  = CONVERGE0(F);

display lrel ;
*---------------------------------------------------------------------
*5. COMMODITY VALUE SHARES FOR HOME CONSUMPTION -------------------
*---------------------------------------------------------------------

PARAMETER
 shrhome(A,C,H) value share for comm'y c in home cons of hhd h from act a
;

 shrhome(A,C,H) = 0;


*----------------------------------------------------------------------
-------------------
*6. INITIALIZATION OF TAX DATA ------------------------------------------
*---------------------------------------------------------------------

SET
 TX  taxes in the model
 /
 INSTAX        direct taxes on domestic institutions
 FACTAX        direct factor taxes
 IMPTAX        import taxes
 EXPTAX        export taxes
 VATAX         value-added taxes
 ACTTAX        taxes on activity revenue
 COMTAX        taxes on commodity sales in domestic market
 /
;

PARAMETER
 TAXPAR(TX,AC)   payment by account ac to tax account tx
 ;

*direct taxes on domestic institutions
```

```
  TAXPAR('INSTAX',INSD)  = SAM('DTAX',INSD);
 *direct factor taxes
  TAXPAR('FACTAX',F)     = SAM('DTAX',F);
 *import taxes
 *TAXPAR('IMPTAX',C)     = 0;
  TAXPAR('IMPTAX',C)     = SAM('MTAX',C);
 *export taxes
 *TAXPAR('EXPTAX',C)     =0;
 TAXPAR('EXPTAX',C)     = SAM('ETAX',C);
 *value-added taxes
  TAXPAR('VATAX',A)      = 0;
 *TAXPAR('VATAX',A)      = SAM('VATAX',A);
 *taxes on activity revenue
  TAXPAR('ACTTAX',A)     = SAM('ETAX',A);
 *taxes on commodity sales in domestic market
  TAXPAR('COMTAX',C)     = SAM('STAX',C);

 PARAMETER
  REGCUTOFF       minimum regional trade share               / 0.00 /
  REGIMP(C,R)     regional imports values
  REGTAR(C,R)     regional tariff values
  REGEXP(C,R)     regional imports values
  REGETX(C,R)     regional tariff values
 ;

--- LOAD  REGIMP = 46:REGIMP
--- LOAD  REGTAR = 47:REGTAR
--- LOAD  REGEXP = 48:REGEXP
--- LOAD  REGETX = 49:REGETX

 *Remove regioanl imports if no national imports in SAM
  REGIMP(C,R)$(NOT SAM('ROW',C)) = 0;
 *Remove small import shares
  REGIMP(C,R)$SUM(RP, REGIMP(C,RP)) = REGIMP(C,R) / SUM(RP, REGIMP(C,RP));
  REGIMP(C,R)$(REGIMP(C,R) LT REGCUTOFF) = 0;
 *Remove regional tariffs if no regional trade
  REGTAR(C,R)$(NOT REGIMP(C,R))  = 0;
 *If no regional trade data then assign to ROW
  REGIMP(C,'ROW')$(NOT SUM(R, REGIMP(C,R))) = 100;
  REGTAR(C,'ROW')$((NOT SUM(R, REGTAR(C,R))) AND SUM(R, REGIMP(C,R))) = 100 ;
 *Recalculate shares
  REGIMP(C,R)$SUM(RP, REGIMP(C,RP)) = REGIMP(C,R) / SUM(RP, REGIMP(C,RP));
```

```
 REGTAR(C,R)$SUM(RP, REGTAR(C,RP)) = REGTAR(C,R) / SUM(RP, REGTAR(C,RP));

*Remove regioanl imports if no national imports in SAM
 REGEXP(C,R)$(NOT SAM('ROW',C)) = 0;
*Remove small import shares
 REGEXP(C,R)$SUM(RP, REGEXP(C,RP)) = REGEXP(C,R) / SUM(RP, REGEXP(C,RP));
 REGEXP(C,R)$(REGEXP(C,R) LT REGCUTOFF) = 0;
*Remove regional tariffs if no regional trade
 REGETX(C,R)$(NOT REGEXP(C,R))  = 0;
*If no regional trade data then assign to ROW
 REGEXP(C,'ROW')$(NOT SUM(R, REGEXP(C,R))) = 100;
 REGETX(C,'ROW')$((NOT SUM(R, REGETX(C,R))) AND SUM(R, REGEXP(C,R))) = 100
 ;
*Recalculate shares
 REGEXP(C,R)$SUM(RP, REGEXP(C,RP)) = REGEXP(C,R) / SUM(RP, REGEXP(C,RP));
 REGETX(C,R)$SUM(RP, REGETX(C,RP)) = REGETX(C,R) / SUM(RP, REGETX(C,RP));

DISPLAY REGIMP, REGTAR, REGEXP, REGETX;

*SAM adjustments ----------------------------------------------------

*In this section, some minor adjustments are made in the SAM (when
*needed) to fit the model structure.

*Adjustment for sectors with only exports and no domestic sales.
*If there is a very small value for domestic sales, add the discrepancy
*to exports.

*Netting transfers between domestic institutions and RoW.
 SAM(INSD,'ROW')   = SAM(INSD,'ROW') - SAM('ROW',INSD);
 SAM('ROW',INSD)   = 0;

*Netting transfers between factors and RoW.
 SAM('ROW',F)  = SAM('ROW',F) - SAM(F,'ROW');
 SAM(F,'ROW')  = 0;

*Netting transfers between government and domestic non-
*government institutions.
 SAM(INSDNG,'GOV') = SAM(INSDNG,'GOV') - SAM('GOV',INSDNG);
 SAM('GOV',INSDNG) = 0;
```

```
*Netting out re-exports of osrv
 SAM('COSRV','ROW') = SAM('COSRV','ROW') - SAM('ROW','COSRV');
 SAM('ROW','COSRV') = 0 ;
*Eliminating payments of any account to itself.
 SAM(ACNT,ACNT) = 0;

*Checking SAM balance ---------------------------------------------

*Account totals are recomputed. Check for SAM balance.
 SAM('TOTAL',ACNT) = SUM(ACNTP, SAM(ACNTP,ACNT));
 SAM(ACNT,'TOTAL') = SUM(ACNTP, SAM(ACNT,ACNTP));

 SAMBALCHK(AC)   = SAM('TOTAL',AC) - SAM(AC,'TOTAL');

 DISPLAY "SAM after final adjustments", SAMBALCHK;
 DISPLAY "SAM after final adjustments", SAM;

*Additional set definitions based on country SAM --------------------

*CD is the set for commodities with domestic sales of domestic output
*i.e., for which (value of sales at producer prices)
*              > (value of exports at producer prices)

 CD(C)  = YES$(SUM(A, SAM(A,C)) GT (SAM(C,'ROW') - TAXPAR('EXPTAX',C) - SUM(CTE, SAM(CTE,C))));
 CDN(C) = NOT CD(C);

 CE(C)  = YES$(SAM(C,'ROW'));
 CEN(C) = NOT CE(C);
 CER(C,R)$(CE(C) AND REGEXP(C,R)) = YES;

 CM(C)  = YES$(SAM('ROW',C));
 CMN(C) = NOT CM(C);
 CMR(C,R)$(CM(C) AND REGIMP(C,R)) = YES;

 CX(C) = YES$SUM(A, SAM(A,C));

 CT(C)$(SUM(CTD, SAM(C,CTD)) + SUM(CTE, SAM(C,CTE)) + SUM(CTM, SAM(C,CTM))
 )  = YES;

display cm, cmn;

*Ghana (sectors with residual exports instead of CET)
SET CERES(C) /
```

```
* coexp
* conut
* cfrue
* cvege
* ccoco
 cfore
 cmine
 /;


*If activity has no intermediate inputs, then Leontief function has to
*be used at the top of the technology nest

 ACES(A)$(NOT SUM(C, SAM(C,A))) = NO;
 ALEO(A)$(NOT ACES(A)) = YES;


DISPLAY
 C, CAGR, CNAGR, R, CD, CDN, CE, CEN, CER, CM, CMN, CMR, CX, CT, ACES, ALEO, FLS;


*Fine-tuning non-SAM data -------------------------------------------

*Generating missing data for home consumption ---

*If SAM includes home consumption but NO data were provided for SHRHOME,
*data are generated assuming that the value shares for home consumption
*are identical to activity output value shares.

IF(SUM((A,H), SAM(A,H)) AND NOT SUM((A,C,H), SHRHOME(A,C,H)),

 SHRHOME(A,C,H)$(SAM(A,H) AND SUM(CP, SAM(A,CP))) = SAM(A,C)/SUM(CP, SAM(A ,CP));

DISPLAY
 "Default data used for SHRHOME -- data missing"
 SHRHOME
 ;
*End IF statement
 );

*Eliminating superfluous elasticity data -------

 TRADELAS(C,'SIGMAT')$(CEN(C) OR (CE(C) AND CDN(C))) = 0;
```

```
 TRADELAS(C,'SIGMAQ')$(CMN(C) OR (CM(C) AND CDN(C))) = 0;

 PRODELAS(A)$(NOT SAM('TOTAL',A))     = 0;

 ELASAC(C)$(NOT SUM(A, SAM(A,C)))     = 0;

 LESELAS1(H,C)$(NOT SAM(C,H))         = 0;
 LESELAS2(A,C,H)$(NOT SHRHOME(A,C,H)) = 0;


*Diagnostics -----------------------------------

*Include file that displays and generates information that may be
*useful when debugging data set.
*$INCLUDE 1DIAGNOSTICS.INC

*Physical factor quantities ---------------------

PARAMETER
 QF2BASE(F,A)  qnty of fac f employed by act a (extracted data)
 ;
*If there is a SAM payment from A to F and supply (but not
*demand) quantities have been defined in the country data file,
*then the supply values are used to compute demand quantities.
 QF2BASE(F,A)$(SAM(F,A)$((NOT QFBASE(F,A))$QFSBASE(F)))
   = QFSBASE(F)*SAM(F,A)/SUM(AP, SAM(F,AP));

*If there is a SAM payment from A to F and neither supply nor
*demand quantities have been defined in the country data file,
*then SAM values are used as quantities
 QF2BASE(F,A)$(SAM(F,A)$((QFBASE(F,A) EQ 0)$(QFSBASE(F) EQ 0)))
                                              = SAM(F,A);

*If there is a SAM payment from A to F and demand quantities have
*been defined in the country data file, then this information is used.
 QF2BASE(F,A)$QFBASE(F,A) = QFBASE(F,A);

DISPLAY QF2BASE, QFBASE, QFSBASE;

*-----------------------------------------------------------------------
*3. PARAMETER DECLARATIONS ----------------------------------------------
*-----------------------------------------------------------------------

```

This section is divided into the following subsections:
a. Parameters appearing in model equations
b. Parameters used for model calibration (to initialize variables and

to define model parameters)

In each group, the parameters are declared in alphabetical order.

```

PARAMETERS

*a. Parameters appearing in model equations ---------------

*Parameters other than tax rates
 alphaa(A)        shift parameter for top level CES function
 alphaac(C)       shift parameter for domestic commodity aggregation fn
 alphae(C)        shift parameter for regional exports aggregation fn
 alpham(C)        shift parameter for regional imports aggregation fn
 alphaq(C)        shift parameter for Armington function
 alphat(C)        shift parameter for CET function
 alphava(A)       shift parameter for CES activity production function
 alphava2(F,A)    Lower level factor nesting parameter
 betah(A,C,H)     marg shr of hhd cons on home com c from act a
 betam(C,H)       marg share of hhd cons on marketed commodity c
 cwts(C)          consumer price index weights
 deltaa(A)        share parameter for top level CES function
 deltaac(A,C)     share parameter for domestic commodity aggregation fn
 deltaq(C,R)      share parameter for Armington function
 deltat(C,R)      share parameter for CET function
 deltava(F,A)     share parameter for CES activity production function
 deltava2(F,FP,A) lower level factor nesting parameter
 dwts(C)          domestic sales price weights
 gammah(A,C,H)    per-cap subsist cons for hhd h on home com c fr act a
 gammam(C,H)      per-cap subsist cons of marketed com c for hhd h
 ica(C,A)         intermediate input c per unit of aggregate intermediate
 inta(A)          aggregate intermediate input coefficient
 iva(A)           aggregate value added coefficient
 icd(C,CP)        trade input of c per unit of comm'y cp produced & sold dom'ly
 ice(C,CP)        trade input of c per unit of comm'y cp exported
 icm(C,CP)        trade input of c per unit of comm'y cp imported
 mps01(INS)       0-1 par for potential flexing of savings rates
 mpsbar(INS)      marg prop to save for dom non-gov inst ins (exog part)
 qdst(C)          inventory investment by sector of origin
 qbarg(C,GOVF)    exogenous (unscaled) government demand by government function
 qbarinv(C)       exogenous (unscaled) investment demand
 rhoa(A)          CES top level function exponent
 rhoac(C)         domestic commodity aggregation function exponent
 rhoe(C)          regional export CES function exponent
 rhom(C)          regional import CES function exponent
 rhoq(C)          Armington function exponent
```

```
rhot(C)          CET function exponent
rhova(A)         CES activity production function exponent
rhova2(F,A)      Lower level factor nesting parameter
shif(INS,F)      share of dom. inst'on i in income of factor f
shifN(INS,F)     share of dom. inst'on i in income of factor f
shii(INS,INSP)   share of inst'on i in post-tax post-sav income of inst
ip
supernum(H)      LES supernumerary income
theta(A,C)       yield of commodity C per unit of activity A
tins01(INS)      0-1 par for potential flexing of dir tax rates
trnsfr(INS,AC)   transfers fr. inst. or factor ac to institution ins
tq01(C)          0-1 par for potential fixing of commodity sales taxes
tqbar(c)         exogenous (unscaled) sales tax rate
INSTQ            index of institutional quality

*Tax rates (sales tax is endogenous)
ta(A)            rate of tax on producer gross output value
te(C,R)          rate of tax on exports
ter(C,R)         rate of tax on regional exports
tf(F)            rate of direct tax on factors (soc sec tax)
tinsbar(INS)     rate of (exog part of) direct tax on dom inst ins
tm(C,R)          rate of import tariff
tva(A)           rate of value-added tax

fprd0(F,A)       productivity of factor f in act a
fprd(F,A)        productivity of factor f in act a
;

*b. Parameters used for model calibration -----------------

```

For model calibration, one parameter is created for each model variable with the suffix "0" added to the variable name. 0 is also added to the names of parameters whose values are changed in experiments.

```

PARAMETERS
v
*Parameters for definition of model parameters
alphae0(C)       shift parameter for regional export aggregation fn
alpham0(C)       shift parameter for regional import aggregation fn
alphava0(A)      shift parameter for CES activity production function
qdst0(C)         stock change
qbarg0(C,GOVF)   exogenous (unscaled) government demand
gammah0(A,C,H)   per-cap subsist cons for hhd h on home com c fr act a
gammam0(C,H)     per-cap subsist cons of marketed com c for hhd h
```

```
alphaq0(C)       shift parameter for Armington function
deltaq0(C,R)     share parameter for CET function
alphat0(C)       shift parameter for Armington function
deltat0(C,R)     share parameter for CET function

ta0(A)           rate of tax on producer gross output value
te0(C,R)         rate of tax on exports
tf0(F)           rate of direct tax on factors (soc sec tax)
tins0(INS)       rate of direct tax on domestic institutions ins
tm0(C,R)         rate of import tariff
tva0(A)          rate of value-added tax

*Check parameters
 cwtschk         check that CPI weights sum to unity
 dwtschk         check that PDIND weights sum to unity
 shifchk         check that factor payment shares sum to unity

*Parameters for variable initialization
 CPI0            consumer price index (PQ-based)
 DPI0            index for domestic producer prices (PDS-based)
 DMPS0           change in marginal propensity to save for selected inst
 DTINS0          change in domestic institution tax share
 DTQ0            change in sales tax rate
 EG0             total current government expenditure
 EH0(H)          household consumption expenditure
 EXR0            exchange rate
 FSAV0           foreign savings
 GADJ0(GOVF)     government demand scaling factor by function
 MGADJ0          government demand scaling factor
 GOVSHR0(GOVF)   govt consumption share of absorption by function
 MGOVSHR0        govt consumption share of absorption
 GSAV0           government savings
 GDEFGDP0        government deficit as a percentage of GDP
 IADJ0           investment scaling factor (for fixed capital formation)
 INVSHR0         investment share of absorption
 MPS0(INS)       marginal propensity to save for dom non-gov inst ins
 MPSADJ0         savings rate scaling factor
 PA0(A)          output price of activity a
 PDD0(C)         demand price for com'y c produced & sold domestically
 PDS0(C)         supply price for com'y c produced & sold domestically
 PE0(C,R)        price of exports
 PINTA0(A)       price of intermediate aggregate
 PM0(C,R)        price of imports
 PQ0(C)          price of composite good c
 PVA0(A)         value added price
 PWE0(C,R)       world price of exports
```

```
PWM0(C,R)       world price of imports
PX0(C)          average output price
PXAC0(A,C)      price of commodity c from activity a
QA0(A)          level of domestic activity
QD0(C)          quantity of domestic sales
QE0(C,R)        quantity of exports
QF0(F,A)        quantity demanded of factor f from activity a
QFS0(F)         quantity of factor supply
QG0(C,GOVF)     quantity of government consumption by government function
QH0(C,H)        quantity consumed of marketed commodity c by hhd h
QHA0(A,C,H)     quantity consumed of home commodity c fr act a by hhd h
QINT0(C,A)      quantity of intermediate demand for c from activity a
QINTA0(A)       quantity of aggregate intermediate input
QINV0(C)        quantity of fixed investment demand
QM0(C,R)        quantity of imports
QQ0(C)          quantity of composite goods supply
QT0(C)          quantity of trade and transport demand for commodity c
QVA0(A)         quantity of aggregate value added
QX0(C)          quantity of aggregate marketed commodity output
QXAC0(A,C)      quantity of ouput of commodity c from activity a
TABS0           total absorption
TINS0(INS)      rate of direct tax on domestic institutions ins
TINSADJ0        direct tax scaling factor
TQ0(C)          sales tax rate
TQADJ0          scaled sales tax adjustment factor
TRII0(INS,INSP) transfers to dom. inst. insdng from insdngp
WALRAS0         savings-investment imbalance (should be zero)
WF0(F)          economy-wide wage (rent) for factor f
WFREAL0(F)      real wage (rent) for factor f
WFDIST0(F,A)    factor wage distortion variable
YF0(f)          factor income
YG0             total current government income
YIF0(INS,F)     income of institution ins from factor f
YI0(INS)        income of (domestic non-governmental) institution ins

*Capital stock updating parameters (only used in the simulation file)
DKAP(FCAP,A)    change in sectoral real capital stock
DKAPS(FCAP)     change in aggregate real capital stock
PKAP(FCAP)      price of aggregate capital good by sector of destination
CAPSHR1(FCAP)   shares of aggregate capital by type (sums to one)
CAPSHR2(FCAP,A) sectoral shares of capital by type (rows sum to one)
CAPSHR1TOT      used to speed up capital accumulation calculations
CAPSHR2TOT(FCAP) used to speed up capital accumulation calculations
BMAT(C,FCAP)    shares of investment goods in aggregate capital by type
BMATTOT         used to speed up capital accumulation calculations
GFCF            gross fixed capital formation
```

```
  RKAP(FCAP,A)     annual rate of growth of sectoral capital stock by type
  RKAPS(FCAP)      annual rate of growth of aggregate capital stock by type
  WFK1AV           average rental on all capital (economywide)
  WFK2AV(FCAP)     average rental on capital by type (across all activities)
  WFDIST2(FCAP,A)  ratio of sectoral to average rental by capital type
  INVSHR1(FCAP)    investment shares by type of capital
  INVSHR2(FCAP,A)  investment shares by sector for each capital type
  NGFCF            GFCF net of exogenous capital adjustments in fixed sectors
  WFDISTADJ(F,A)   WFDIST adjusted to exclude fixed sectors
  WFADJ(F)         WF adjusted to exclude fixed sectors
  beta1            capital mobility parameter by type      / 2.00 /
  beta2            capital mobility by sector              / 2.00 /
  INSTQ            index of institutional quality          /6.0  /
;

*---------------------------------------------------------------------
*4. PARAMETER DEFINITIONS --------------------------------------------
*---------------------------------------------------------------------


*All parameters are defined, divided into the same blocks as the
*equations.

*Price block ----------------------------------

  The prices PDS, PX, and PE  may be initialized at any desired price.
  The user may prefer to initialize these prices at unity or, if
  he/she is interested in tracking commodity flows in physical units, at
  commodity-specific, observed prices (per physical unit). For any given
  commodity, these three prices should be identical. Initialization at
  observed prices may be attractive for disaggregated agricultural
  commodities. If so, the corresponding quantity values reflect physical
  units (given the initial price).

  The remaining supply-side price, PXAC, and the non-commodity prices, EXR
  and PA may be initialized at any desired level. In practice, it may be
  preferable to initialize PXAC at the relevant supply-side price and EXR
  and PA at unity.

  If physical units are used, the user should select the unit (tons vs.
  '000 tons) so that initial price and quantity variables are reasonably
  scaled (for example between 1.0E-2 and 1.0E+3) -- bad scaling may cause
  solver problems. Initialization at unity should cause no problem as long
  as the initial SAM is reasonably scaled.

PARAMETER
```

```
 * PSUP(C)               initial supply-side market price for commodity c
 * PSUPA(AAG)            initial supply-side market price for commodity c
  PRODUCTION(A,*)        production quantity information used to calibrate
      initial activity prices
 * prodshr(a)
 ;

 *$ONTEXT
--- LOAD  PRODUCTION = 53:PRODUCTION

  PA0(A)      = 1;
  PA0(A)$PRODUCTION(A,'PROD') = SAM('TOTAL',A) /
(PRODUCTION(A,'PROD')/1000
     );
 * PA0(AAGR) = 2;

 * prodshr(a)$SUM((AAG,AP)$(MAPAAGA(AAG,A) AND MAPAAGA(AAG,AP)),
SAM('TOTAL
     ',AP)) = SAM('TOTAL',A)/SUM((AAG,AP)$(MAPAAGA(AAG,A) AND
MAPAAGA(AAG,AP)),
      SAM('TOTAL',AP));
 * PSUPA(AAG) = SUM(A$MAPAAGA(AAG,A), PRODSHR(A)*PA0(A));

 * PSUP(C) = SUM((AAG,A)$(MAPAAGA(AAG,A) AND MAPA2C(AAG,C)),
PRODSHR(A)*PA0
     (A));

 * PSUP(C) = 1;
 * PE0(C,R)$CER(C,R)   = PSUP(C);
 * PX0(C)$CX(C)        = PSUP(C);
 * PDS0(C)$CD(C)       = PSUP(C);
 * PXAC0(A,C)$SAM(A,C) = PSUP(C);



      PA0(A)            = 1;
      PSUP(C)           = 1;
      PE0(C,R)$CER(C,R)   = PSUP(C);
      PX0(C)$CX(C)        = PSUP(C);
      PDS0(C)$CD(C)       = PSUP(C);
      PXAC0(A,C)$SAM(A,C) = PSUP(C);

```

The exchange rate may be initialized at unity, in which case all data are in foreign currency units (FCU; e.g., dollars). Set the exchange rate at another value to differentiate foreign exchange transactions, which will be valued in FCU, and domestic transactions valued in local currency units (LCU). The SAM is assumed to be valued in LCU, and the exchange rate is then used to calculate FCU values for transactions with the rest of the world.

```
 EXR0         = 9073 ;

*Activity quantity = payment to activity divided by activity price
*QA covers both on-farm consumption and marketed output
*output GROSS of tax
 QA0(A)       =  SAM('TOTAL',A)/PA0(A) ;

*Output quantity = value received by producers divided by producer
*price
*QX covers only marketed output
* QX0(C)$SUM(A, SAM(A,C)) =  SUM(A, SAM(A,C)) / PX0(C);

 QX0(C) =  SUM((AAG,A)$(MAPAAGA(AAG,A) AND MAPA2C(AAG,C)), QA0(A));
 PX0(C)$QX0(C) =  SUM(A, SAM(A,C)) / QX0(C);

 PE0(C,R)$CER(C,R)   = PX0(C);
 PDS0(C)$CD(C)       = PX0(C);
 PXAC0(A,C)$SAM(A,C) = PX0(C);

*Unit value-added price = total value-added / activity quantity
*define pva gross of tax
 QVA0(A)        =  (SUM(F, SAM(F,A))+ TAXPAR('VATAX',A)) ;
 PVA0(A)$QVA0(A) =  (SUM(F, SAM(F,A))+ TAXPAR('VATAX',A))/QVA0(A);
 iva(A)$QA0(A)   =  QVA0(A)/QA0(A) ;
 QXAC0(A,C)$SAM(A,C) = SAM(A,C) / PXAC0(A,C);

 QHA0(A,C,H)$SHRHOME(A,C,H) = SHRHOME(A,C,H)*SAM(A,H)/PXAC0(A,C);


*display PA0,  prodshr, PSUPA, PSUP;


*Export quantity = export revenue received by producers
*(ie. minus tax and transactions cost) divided by
*export price.
PARAMETER
 TRESHR(C,R)
;

 TRESHR(C,R)$SUM(RP,
SAM(C,'ROW')*REGEXP(C,RP)+TAXPAR('EXPTAX',C)*REGETX(C
,RP))
```

```
        = (SAM(C,'ROW')*REGEXP(C,R)+TAXPAR('EXPTAX',C)*REGETX(C,R)) / SUM (RP, SAM(C,'ROW')*REGEXP(C,RP)+TAXPAR('EXPTAX',C)*REGETX(C,RP));

 QE0(C,R)$CER(C,R) = (SAM(C,'ROW')*REGEXP(C,R)
                  - TAXPAR('EXPTAX',C)*REGETX(C,R)
                  - SUM(CTE, SAM(CTE,C))*TRESHR(C,R) )/PE0(C,R);

* QE0(C)$SAM(C,'ROW')
*    =  (SAM(C,'ROW') - TAXPAR('EXPTAX',C) - SUM(CTE, SAM(CTE,C)))/PE0(C);

*RoW export price = RoW export payment (in for curr) / export qnty
 PWE0(C,R)$CER(C,R)  = (SAM(C,'ROW')*REGEXP(C,R)/EXR0) / QE0(C,R);

 te0(C,R)$(SAM(C,'ROW')*REGEXP(C,R)) = (TAXPAR('EXPTAX',C)*REGETX(C,R))/(SAM(C,'ROW')*REGEXP(C,R));
 te(C,R)             = te0(C,R);
*te0(C,R)             =0;
*Quantity of output sold domestically = output quantity less quantity
*exported = value of domestic sales divided by domestic supply price
*QD0 covers only marketed output
 QD0(C)$CD(C) =  QX0(C) - SUM(R, QE0(C,R));

*Domestic demander price = demander payment divided by quantity bought
 PDD0(C)$QD0(C)= (PDS0(C)*QD0(C) + SUM(CTD, SAM(CTD,C)))/QD0(C);

*Define import price to equal domestic price so that import and domestic
*units are the same to the purchaser. If no domestic good, set PM to 1.
 PM0(C,R)$CMR(C,R) = PDD0(C) ;
 PM0(C,R)$(QD0(C) EQ 0)  = 1 ;

*Import quantity = demander payment for imports (including tariffs
*and marketing cost) divided by demander price.
PARAMETER
 TRMSHR(C,R)
;

 TRMSHR(C,R)$SUM(RP, SAM('ROW',C)*REGIMP(C,RP)+TAXPAR('IMPTAX',C)*REGTAR(C,RP))
        = (SAM('ROW',C)*REGIMP(C,R)+TAXPAR('IMPTAX',C)*REGTAR(C,R)) / SUM (RP, SAM('ROW',C)*REGIMP(C,RP)+TAXPAR('IMPTAX',C)*REGTAR(C,RP));

 QM0(C,R)$CMR(C,R) = (SAM('ROW',C)*REGIMP(C,R)
```

```
                  + TAXPAR('IMPTAX',C)*REGTAR(C,R)
                  + SUM(CTM, SAM(CTM,C))*TRMSHR(C,R) )/PM0(C,R);

*World price = import value (in foreign currency / import quantity)
 PWM0(C,R)$CMR(C,R)                 = (SAM('ROW',C)*REGIMP(C,R)/EXR0) / QM0(C,R);
 tm0(C,R)$(SAM('ROW',C)*REGIMP(C,R)) = (TAXPAR('IMPTAX',C)*REGTAR(C,R)) / (SAM('ROW',C)*REGIMP(C,R));
 tm(C,R)                            = tm0(C,R);

*Composite supply is the sum of domestic market sales and imports
*(since they are initialized at the same price).
 QQ0(C)$(CD(C) OR CM(C)) = QD0(C) + SUM(R, QM0(C,R)) ;
 PQ0(C)$QQ0(C) = (SAM(C,'TOTAL') - SAM(C,'ROW'))/QQ0(C);
 TQ0(C)$QQ0(C) = TAXPAR('COMTAX',C)/(PQ0(C)*QQ0(C)) ;
 tqbar(C)      = TQ0(C) ;

*The following code works when for any number of sectors providing
*transactions services, as well as for the case when they are not
*in the SAM.

PARAMETERS
 SHCTD(C)  share of comm'y ct in trans services for domestic sales
 SHCTM(C)  share of comm'y ct in trans services for imports
 SHCTE(C)  share of comm'y ct in trans services for exports
 ;

 SHCTD(CT) = SUM(CTD, SAM(CT,CTD)/SAM('TOTAL',CTD)) ;
 SHCTM(CT) = SUM(CTM, SAM(CT,CTM)/SAM('TOTAL',CTM)) ;
 SHCTE(CT) = SUM(CTE, SAM(CT,CTE)/SAM('TOTAL',CTE)) ;

*Transactions input coefficients
 icd(CT,C)$QD0(c) = (shctd(ct)*SUM(CTD, SAM(CTD,C))/PQ0(ct)) / QD0(C);

 icm(CT,C)$SUM(R, QM0(C,R)) = (shctm(ct)*SUM(CTM, SAM(CTM,C))/PQ0(ct)) / SUM(R, QM0(C,R));

 ice(CT,C)$SUM(R, QE0(C,R)) = (shcte(ct)*SUM(CTE, SAM(CTE,C))/PQ0(ct)) / SUM(R, QE0(C,R));

*Indirect activity tax rate = tax payment / output value
*Tax is here applied to total output value (incl. on-farm cons.)
 tva0(A)$(PVA0(A)*QVA0(A)) = TAXPAR('VATAX',A) / (PVA0(A)*QVA0(A));
 tva(A)       = tva0(A);
```

```

*QA is GROSS of tax, so base for ta is as well
 ta0(A)$SAM(A,'TOTAL') = TAXPAR('ACTTAX',A) / (SAM(A,'TOTAL'));
 ta(A)         = ta0(A);

*Yield coefficient
* = quantity produced (including home-consumed output)
*   /activity quantity
 theta(A,C)$PXAC0(A,C)
  = ( (SAM(A,C) + SUM(H, SHRHOME(A,C,H)*SAM(A,H)) ) / PXAC0(A,C) ) / QA0(A);

* LEOAGGINT(A)$ALEO(A).. PINTA(A)*QINTA(A) =E= inta(A)*PA(A)*QA(A) ;
* INTDEM(C,A)$ica(C,A).. PQ(C)*QINT(C,A) =E= ica(C,A)*PINTA(A)*QINTA(A);

*OLD
 QINT0(C,A)$PQ0(C) = SAM(C,A) / PQ0(C);
 QINTA0(A) = SUM(C$PQ0(C), SAM(C,A)  / PQ0(C)) ;

 inta(A)$QA0(A) = QINTA0(A) / QA0(A) ;

 ica(C,A)$(QINTA0(A)$PQ0(C)) = SAM(C,A)/PQ0(C) / QINTA0(A) ;

 pinta0(A)      = SUM(C, ica(C,A)*PQ0(C)) ;



DISPLAY QINT0, QINTA0, PINTA0, ICA, INTA;



*CPI weight by comm'y = hhd cons value for comm'y / total hhd cons value
*CPI does not consider on-farm consumption.
 cwts(C)       = SUM(H, SAM(C,H)) / SUM((CP,H), SAM(CP,H));

*Domestic sales price index weight = dom sales value for comm'y
*/ total domestic salues value
*Domestic sales price index does not consider on-farm consumption.
 dwts(C)       = (SUM(A, SAM(A,C)) - (SAM(C,'ROW') -
                 SUM(cte, SAM(cte,C))))/
                 SUM(CP, SUM(A, SAM(A,CP)) - (SAM(CP,'ROW') -
                 SUM(cte, SAM(cte,CP))));

 CWTSCHK       = SUM(C, cwts(C));
 DWTSCHK       = SUM(C, dwts(C));

```

```
 CPI0         = SUM(C, cwts(C)*PQ0(C)) ;
 DPI0         = SUM(CD, dwts(CD)*PDS0(CD)) ;

DISPLAY CWTSCHK, DWTSCHK;

*Production and trade block -------------------------

*Compute exponents from elasticites
 rhoq(C)$(CM(C) AND CD(C))  = (1/TRADELAS(C,'SIGMAQ')) - 1;

 rhot(C)$(CE(C) AND CD(C))  = (1/TRADELAS(C,'SIGMAT')) + 1;
 rhova(A)$PRODELAS(A)       = (1/PRODELAS(A)) - 1;
 rhoa(A)$ACES(A)            = (1/PRODELAS2(A)) - 1;

 rhova2(F,A)$SUM(FP, MFA2(F,FP,A)) = (1/PRODELAS3(F,A)) - 1;

*Aggregation of domestic output from different activities

 RHOAC(C)$ELASAC(C) = 1/ELASAC(C) - 1;

 deltaac(A,C)$ (SAM(A,C)$ELASAC(C))
              = (PXAC0(A,C)*QXAC0(A,C)**(1/ELASAC(C)))/
                SUM(AP, PXAC0(AP,C)*QXAC0(AP,C)**(1/ELASAC(C)));

 alphaac(C)$SUM(A,deltaac(A,C))
              = QX0(C)/
                (SUM(A$deltaac(A,C), deltaac(A,C) * QXAC0(A,C)
                **(-RHOAC(C))) )**(-1/RHOAC(C));

PARAMETERS
 WFA(F,A)          wage for factor f in activity a (used for calibration)
 ;

*Demand computations ----

SET
 MFAGG(F,FP,A) directly or indirectly factor F is an agg of FP
*This mapping links aggregate factor F to ALL disaggregate factors
*that are below it in the nest (ie FP).
 ;

* MFAGG(F,FDIS,A)$(MFA2(F,FDIS,A) + SUM(FAGG, MFA2(F,FAGG,A)*MFA2(FAGG,FDIS,A))) = YES;
* MFAGG(F,FDIS,A)$MFA2(F,FDIS,A) = YES;
*The definition of MFAGG could be generalized further.
```

```

* MFAGG(F,FLAB,A)$(SUM(FP, FTREE(F,FP,FLAB)) AND SAM(FLAB,A)) = YES;
 MFAGG(F,FP,A)$((SUM(FPP, FTREE(F,FPP,FP)) AND SAM(FP,A)) AND FDIS(FP))
=
 YES;

DISPLAY AC, FAGG, MFAGG, FDIS, FTREE, FNEST;

*Defining factor employment and supply.
 QF0(F,A)  = QF2BASE(F,A);
*Defining employment for aggregate factors in factor nesting
 QF0(FAGG,A) = SUM(FDIS$MFAGG(FAGG,FDIS,A), QF0(FDIS,A));
*Total factor supply is sum of sectoral factor demand
 QFS0(F)   = SUM(A, QF0(F,A));

*Activity-specific wage is activity labor payment over employment
 WFA(F,A)$SAM(F,A) = SAM(F,A)/QF0(F,A);
*Activity-specific wages for aggregate factors in factor nesting
 WFA(FAGG,A)$QF0(FAGG, A)
  = SUM(FDIS$MFAGG(FAGG,FDIS,A), SAM(FDIS,A))/QF0(FAGG,A);

*Economy-wide wage average is total factor income over employment
 WF0(F)$SUM(A, SAM(F,A)) = SUM(A, SAM(F,A))/SUM(A, QF0(F,A));

 WF0(FAGG)$SUM(A, QF0(FAGG,A))
   = SUM((FDIS,A)$MFAGG(FAGG,FDIS,A), SAM(FDIS,A))
    /SUM(A, QF0(FAGG,A));

*Economy-wide real wage average. Defined as equal to WF in base.
 WFREAL0(F) = WF0(F);

*Factor-specific productivity adjustment parameter
 fprd0(F,A)         = 1;
 fprd(F,A)          = fprd0(F,A);

PARAMETER
  QFS0T(F)      tempory storage for flexible labor supply equation
  WF0T(F)       tempory storage for flexible labor supply equation
;

  QFS0t(F) = QFS0(F);
  WF0t(F)  = WF0(F) ;

DISPLAY
"If the value of WF0 for any factor is very different from one (< 0.1"
"or >10) the user may consider rescaling the initial values for QFBASE"
```

```
"or QFSBASE for this factor to get a value of WF0 such that"
"0.1 < WF0 < 10"
 WF0
 ;

*Wage distortion factor
 wfdist0(F,A)$WF0(F) = WFA(F,A)/WF0(F);

*CES activity production function
 deltava(F,A)$MFA1(F,A)
           = (wfdist0(F,A) * WF0(F)
             * (QF0(F,A))**(1+rhova(A)) )
             / SUM(FP$MFA1(FP,A), wfdist0(FP,A) * WF0(FP)*(QF0(FP,A))**(1+rhova(A)));

  alphava0(A)$rhova(A) = QVA0(A)/( SUM(F$MFA1(F,A), deltava(F,A)*QF0(F,A)
              **(-rhova(A))) )**(-1/rhova(A));

 alphava(A) = alphava0(A);

*Lower layer nested factor substitution parameters

 deltava2(F,FP,A)$MFA2(F,FP,A)
   = (wfdist0(FP,A) * WF0(FP) * (QF0(FP,A))**(1+rhova2(F,A)) )
     / SUM(FPP$MFA2(F,FPP,A), wfdist0(FPP,A) * WF0(FPP)*(QF0(FPP,A))**(1+rhova2(F,A)));

  alphava2(F,A)$SUM(FP, MFA2(F,FP,A))
   = QF0(F,A)/( SUM(FP$MFA2(F,FP,A), deltava2(F,FP,A)*QF0(FP,A)
              **(-rhova2(F,A))) )**(-1/rhova2(F,A));

DISPLAY deltava2, alphava2;

*CES top level production function
PARAMETER
 predeltaa(A)  dummy used to define deltaa ;

 predeltaa(A)  = 0 ;
 predeltaa(A)$(ACES(A) AND QINTA0(A))
               = (PVA0(A)/PINTA0(A))*(QVA0(A)/QINTA0(A))**(1+rhoa(A)) ;
 deltaa(A)$ACES(A) = predeltaa(A)/(1 + predeltaa(A)) ;
 alphaa(A)$deltaa(A)
               = QA0(A)/((deltaa(A)*QVA0(A)**(-rhoa(A))
                 +(1-deltaa(A))*QINTA0(A)**(-rhoa(A)))**(-1/rhoa(A))) ;

*Transactions demand
```

```
QT0(CT) = ( SUM(CTD, SAM(CT,CTD)) + SUM(CTE, SAM(CT,CTE))
            + SUM(CTM, SAM(CT,CTM)) ) / PQ0(CT) ;

*CET transformation
deltat0(C,R)$CER(C,R)
  = (PE0(C,R)*(QE0(C,R))**(1-rhot(C)))/( SUM(RP$CER(C,RP), PE0(C,RP)*QE0(C,RP)**(1-rhot(C))) + (PDS0(C)*QD0(C)**(1-rhot(C))) );
deltat(C,R) =  deltat0(C,R);

alphat0(C)$(CE(C) AND CD(C))
  = QX0(C)/(SUM(R$CER(C,R), deltat(C,R)*QE0(C,R)**rhot(C))  + ((1-SUM(R$CER(C,R), deltat(C,R)))*QD0(C)**( rhot(C))) )**(1/rhot(C));
alphat(C) =  alphat0(C);

*Armington aggregation
deltaq0(C,R)$CMR(C,R) = (PM0(C,R)*(QM0(C,R))**(1+rhoq(C)))/( SUM(RP$CMR(C,RP), PM0(C,RP)*QM0(C,RP)**(1+rhoq(C))) + (PDD0(C)*QD0(C)**(1+rhoq(C))) );
deltaq(C,R)       = deltaq0(C,R);

alphaq0(C)$(CM(C) AND CD(C))
  = QQ0(C)/(SUM(R$CMR(C,R), deltaq(C,R)*QM0(C,R)**(-rhoq(C))) + ((1-SUM(R$CMR(C,R), deltaq(C,R)))*QD0(C)**(-rhoq(C))) )**(-1/rhoq(C));
alphaq(C)         = alphaq0(C);


*Institution block ------------------------------

*Institutional income
YI0(INSDNG) = SAM('TOTAL',INSDNG);

*Factor income by factor category
YF0(F) = SUM(A, SAM(F,A));

*Institution income from factors
YIF0(INSD,F) = SAM(INSD,F);

*Transfers to RoW from factors
trnsfr('ROW',F) = SAM('ROW',F)/EXR0;

*Transfers from RoW to institutions
trnsfr(INSD,'ROW') = SAM(INSD,'ROW')/EXR0;

*Government transfers
trnsfr(INSD,'GOV') = SAM(INSD,'GOV')/CPI0;

*Factor taxes
```

```
 tf0(F)$SAM('TOTAL',F)        = TAXPAR('FACTAX',F)/SAM('TOTAL',F);
 tf(F)         = tf0(F);

*Shares of domestic institutions in factor income (net of factor taxes
*and transfers to RoW).
 shif(INSD,F)$SAM(F,'TOTAL')  = SAM(INSD,F)/(SAM(F,'TOTAL') - TAXPAR('FACTAX',f)
                  - SAM('ROW',F));
*XD 2007Dec
parameter
QFSA0(INSD,F)
QFSN0(INSD,F)
QFST0(INSD,F)
;

QFSA0('hcrur',F)  = sum(A$(AAGR(A) and MAPAZONE(A,'zone1')),SAM(F,A)) ;
QFSA0('hfrur',F)  = sum(A$(AAGR(A) and MAPAZONE(A,'zone2')),SAM(F,A)) ;
QFSA0('hssru',F)  = sum(A$(AAGR(A) and MAPAZONE(A,'zone3')),SAM(F,A)) ;
QFSA0('hsnru',F)  = sum(A$(AAGR(A) and MAPAZONE(A,'zone4')),SAM(F,A)) ;
QFST0(INSD,F) = SAM(INSD,F) ;
display shif, QFSA0, QFST0;

 shifN(INSD,F) = 0 ;
 shifN('hcrur',F)$(SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)))  =
                          (SAM('hcrur',F) - sum(A$(AAGR(A) and MAPAZONE(A,'zone1')),SAM(F,A)))/
                               (SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)) - TAXPAR('FACTAX',F) - SAM('ROW',F));
 shifN('hfrur',F)$(SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)))  =
                          (SAM('hfrur',F) - sum(A$(AAGR(A) and MAPAZONE(A,'zone2')),SAM(F,A)))/
                               (SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)) - TAXPAR('FACTAX',F) - SAM('ROW',F));
 shifN('hssru',F)$(SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)))  =
                          (SAM('hssru',F) - sum(A$(AAGR(A) and MAPAZONE(A,'zone3')),SAM(F,A)))/
                               (SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)) - TAXPAR('FACTAX',F) - SAM('ROW',F));
 shifN('hsnru',F)$(SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)))  =
                          (SAM('hsnru',F) - sum(A$(AAGR(A) and MAPAZONE(A,'zone4')),SAM(F,A)))/
                               (SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)) - TAXPAR('FACTAX',F) - SAM('ROW',F));

 shifN(H,F)$(HURB(H) and SAM(H,F)) = SAM(H,F)/
                 (SAM(F,'TOTAL') - sum(A$AAGR(A),SAM(F,A)) - TAXPAR('FACTAX
```

```
',F) - SAM('ROW',F));


 SHIFCHK(F)    = SUM(INSD, shif(INSD,F));
 DISPLAY  SHIFCHK;

 SHIFCHK(F)    = 0;
 SHIFCHK(F)    = SUM(INSD, shifN(INSD,F));
 DISPLAY  shifn, shif, SHIFCHK;

*Inter-institution transfers
 TRII0(INSDNG,INSDNGP) = SAM(INSDNG,INSDNGP);

*Share of dom non-gov institution in income of other dom non-gov
*institutions (net of direct taxes and savings).
 shii(INSDNG,INSDNGP)$(SAM('TOTAL',INSDNGP) -
TAXPAR('INSTAX',INSDNGP) - S
AM('S-I',INSDNGP))
  = SAM(INSDNG,INSDNGP)
   /(SAM('TOTAL',INSDNGP) - TAXPAR('INSTAX',INSDNGP) - SAM('S-
I',INSDNGP))
;

*Scaling factors for savings, sales and direct tax shares
 MPSADJ0      = 0;
 TINSADJ0     = 0;
 TQADJ0       = 0;


*Savings rates
 MPS0(INSDNG)$(SAM('TOTAL',INSDNG) - TAXPAR('INSTAX',INSDNG))
  = SAM('S-I',INSDNG)/(SAM('TOTAL',INSDNG) - TAXPAR('INSTAX',INSDNG));
 mpsbar(INSDNG) = MPS0(INSDNG);

*Direct tax rates
 TINS0(INSDNG)$SAM('TOTAL',INSDNG)
  = TAXPAR('INSTAX',INSDNG) / SAM('TOTAL',INSDNG);
 tinsbar(INSDNG) = TINS0(INSDNG);

*"Point" change in savings, sales and direct tax shares
 DMPS0  = 0;
 DTINS0 = 0;
 DTQ0   = 0;

*Selecting institutions for potential "point" change in savings and tax ra
tes
```

```

*If DMPS or MPSADJ is flexible, institutions with a value of 1 for mps01
*change their savings rates.
 mps01(INSDNG)  = 1;

*If DTIMS is flexible, institutions with a value of 1 for tins01 change
*their savings rates.
 tins01(INSDNG) = 1;

*If DTQ is flexible, commodities with a value of 1 for tq01 change
*their sales tax rates.
 tq01(C) = 1;

*Household consumption spending and consumption quantities.
 EH0(H)$SAM(H,'TOTAL')        = SUM(C, SAM(C,H)) + SUM(A, SAM(A,H));
 QH0(C,H)$PQ0(C) = SAM(C,H)/PQ0(C);

*Government indicators
 YG0                = SAM('TOTAL','GOV');
 EG0                = SAM('TOTAL','GOV') - SAM('S-I','GOV');
 QG0(C,GOVF)$(PQ0(C) AND SUM(GOVFP, GOVFSHR(C,GOVFP))) = SAM(C,'GOV')/PQ0(C) * (GOVFSHR(C,GOVF)/SUM(GOVFP, GOVFSHR(C,GOVFP)));

 qbarg0(C,GOVF) = QG0(C,GOVF);
 qbarg(C,GOVF)  = qbarg0(C,GOVF);
 GADJ0(GOVF)    = 1;
 MGADJ0         = 1;
 GSAV0          = SAM('S-I','GOV');

*LES calibration -----------------------------------------

PARAMETERS
 BUDSHRtot(H)
 BUDSHR(C,H)    budget share for marketed commodity c and household h
 BUDSHR2(A,C,H) budget share for home commodity c - act a - hhd h
 BUDSHRCHKtot(H)
 BUDSHRCHK(H)   check that budget shares some to unity
 ELASCHK(H)     check that expenditure elasticities satisfy Engel aggr
*====
*Xinshen
 shgammam0(C,H)
 shavggammam0(C)
 avgQH0(C)
 LESELAS1larg(H,C)
 betamlarg(C,H)
```

```

 ;

 BUDSHRtot(H)   = (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H)));
 BUDSHR(C,H)$BUDSHRtot(H)    = SAM(C,H)/ BUDSHRtot(H);

 BUDSHR2(A,C,H)$BUDSHRtot(H) = SAM(A,H)*SHRHOME(A,C,H)
/BUDSHRtot(H);

 BUDSHRCHK(H)   = SUM(C, BUDSHR(C,H)) + SUM((A,C), BUDSHR2(A,C,H));

 ELASCHK(H)     = SUM(C, BUDSHR(C,H)*LESELAS1(H,C))
                 + SUM((A,C), BUDSHR2(A,C,H)*LESELAS2(A,C,H));

DISPLAY BUDSHR, BUDSHR2, BUDSHRCHK, LESELAS1, LESELAS2, ELASCHK;

 LESELAS1(H,C)$ELASCHK(H)   = LESELAS1(H,C)/ELASCHK(H);
 LESELAS2(A,C,H)$ELASCHK(H) = LESELAS2(A,C,H)/ELASCHK(H);

 ELASCHK(H)      = SUM(C, BUDSHR(C,H)*LESELAS1(H,C))
                  + SUM((A,C), BUDSHR2(A,C,H)*LESELAS2(A,C,H));

DISPLAY ELASCHK, LESELAS1, LESELAS2;


 betam(C,H)   = BUDSHR(C,H)*LESELAS1(H,C);
 betah(A,C,H) = BUDSHR2(A,C,H)*LESELAS2(A,C,H);

*===
*Xinshen
 LESELAS1larg(H,C)$( LESELAS1(H,C)gt 1) =  LESELAS1(H,C) ;
 betamlarg(C,H)$(2*betam(C,H) gt BUDSHR(C,H)) = QH0(c,h) ;

 parameter
 FRISCHC(C,H)
 ;

* FRISCH(H) = 1.5*FRISCH(H);
 FRISCHC(C,H)$(BUDSHR(C,H) + betam(C,H)/FRISCH(H) lt 0) = 1.5*FRISCH(H);
 FRISCH(H)$sum(c,FRISCHC(C,H)) = smin(c, FRISCHC(C,H)) ;

 gammam0(C,H)$BUDSHR(C,H)
     =  ( (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H))) / PQ0(C) )
                    * ( BUDSHR(C,H) + betam(C,H)/FRISCH(H));

 FRISCHC(C,H)$(BUDSHR(C,H) + betam(C,H)/FRISCH(H) lt 0) = 2.05*FRISCH(H);
```

```
 FRISCH(H)$sum(c,FRISCHC(C,H)) = smin(c, FRISCHC(C,H)) ;


 gammam0(C,H)$BUDSHR(C,H)
    =  ( (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H))) / PQ0(C) )
                  * ( BUDSHR(C,H) + betam(C,H)/FRISCH(H));

 gammah0(A,C,H)$BUDSHR2(A,C,H)
    =  ( (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H))) / PXAC0(A,C) )
                  * ( BUDSHR2(A,C,H) + betah(A,C,H)/FRISCH(H));

 gammam(C,H)   =  gammam0(C,H);

 gammah(A,C,H) =  gammah0(A,C,H);

*===
*Xinshen
shavggammam0(C)$sum(H,QH0(C,H))  = 100*sum(H,gammam(C,H))/sum(H,QH0(C,H))
;
shgammam0(C,H)$QH0(C,H)  = 100*gammam(C,H)/QH0(C,H) ;
avgQH0(C) = sum(H,QH0(C,H)) ;

 display frisch, LESELAS1larg, betamlarg, avgQH0, shavggammam0, shgammam0;

*Checking LES parameters ---------------------------------
PARAMETERS
 SUBSIST(H)  subsistence spending
 FRISCH2(H)  alt. defn of Frisch -- ratio of cons to supernumerary cons
 LESCHK(H)   check on LES parameter definitions (error mssg if error)

 LESELASP(H,*,C,*,CP) price elasticity bt c and cp for h (with c and cp la
beled by source)
*LESELASP defines cross-price elasticities when c is different from cp and
*own-price elasticities when c and cp refer to the same commodity.
*Source: Dervis, de Melo and Robinson. 1982. General Equilibrium Models
*for Development Policy. Cambridge University Press, p. 483
 ;
 SUPERNUM(H)  = SUM((A,C), gammah(A,C,H)*PXAC0(A,C))
               + SUM(C, gammam(C,H)*PQ0(C)) ;
 FRISCH2(H)$(EH0(H) - SUPERNUM(H))   = -EH0(H)/(EH0(H) - SUPERNUM(H));
 LESCHK(H)$((ABS(FRISCH(H) - FRISCH2(H)) GT 0.00000001) AND (SUM(A,
SAM(A,
H))+SUM(C, SAM(C,H)))) = 1/0;

PARAMETER  SUPINCSHR(H);

```

```
SUPINCSHR(H)$EH0(H) = SUPERNUM(H)/EH0(H)*100;

DISPLAY "Supernumerary expenditure as a percentage of total household expe
nditure", FRISCH2, SUPINCSHR, LESCHK;

*Cross-price elasticities : COMPUATATION IS TIME CONSUMING (BEST LEFT OUT
OF COMPILATION)

 LESELASP(H,'MRK',C,'MRK',CP)$(ORD(C) NE ORD(CP))
   = -LESELAS1(H,C)
     * PQ0(CP)*gammam(CP,H) / (SUM(CPP, SAM(CPP,H)) + SUM(APP, SAM(APP,H))
);

 LESELASP(H,A,C,'MRK',CP)$(ORD(C) NE ORD(CP))
   = -LESELAS2(A,C,H)
     * PQ0(CP)*gammam(CP,H) / (SUM(CPP, SAM(CPP,H)) + SUM(APP, SAM(APP,H))
);

 LESELASP(H,'MRK',C,A,CP)$(ORD(C) NE ORD(CP))
   = -LESELAS1(H,C)
     * PXAC0(A,CP)*gammah(A,CP,H) / (SUM(CPP, SAM(CPP,H)) + SUM(APP, SAM(A
PP,H)));

*Own-price elasticities

 LESELASP(H,'MRK',C,'MRK',C)
   = -LESELAS1(H,C)
     *( PQ0(C)*gammam(C,H) / (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H)))
                                        - 1/FRISCH(H));

 LESELASP(H,A,C,A,C)
   = -LESELAS2(A,C,H)
     *( PXAC0(A,C)*gammah(A,C,H) / (SUM(CP, SAM(CP,H)) + SUM(AP, SAM(AP,H)
))
                                        - 1/FRISCH(H));

OPTION LESELASP:3:2:2;

DISPLAY
 SUPERNUM, FRISCH, FRISCH2, LESCHK, LESELASP
 ;


*System-constraint block -------------------------
*Calibrate GDP growth for baseline
PARAMETER
```

```
 QINVK          quantity of new investment capital
 PINV           price of new investment capital
 alphainv       shift parameter for investment
 iwts(C)        weights for investment price index
 gdpgr          calibrated GDP growth rate for baseline scenario        / 0.045 /
 depreciation   capital depreciation rate                               / 0.04 /

 ;

*Fixed investment
 qbarinv(c)$CINV(C) = SAM(C,'S-I')/PQ0(C);
 QINV0(C)          = qbarinv(C);
 IADJ0             = 1;

IF (KOPTION EQ 2,
 QINVK          = (depreciation + gdpgr) * SUM(FCAP, CAPSTK(FCAP));
 PINV           = SUM(C, SAM(C,'S-I')) / QINVK;
 iwts(C)        = qbarinv(c) / SUM(CP, qbarinv(cP));
 alphainv       = PINV / SUM(C, iwts(c)*PQ0(C));
 DISPLAY        QINVK, PINV, alphainv, gdpgr, depreciation, iwts, INSTQ;
);

*Stock changes
 qdst0(C)$PQ0(C) = (SAM(C,'S-I')$(NOT CINV(C)) + SAM(C,'DSTK'))/PQ0(C);
 qdst(C)        = qdst0(C);

 FSAV0        = SAM('S-I','ROW')/EXR0;

 TABS0        = SUM((C,H), SAM(C,H)) + SUM((A,H), SAM(A,H))
              + SUM(C, SAM(C,'GOV')) + SUM(C, SAM(C,'S-I'))
              + SUM(C, SAM(C,'DSTK'));

 INVSHR0      = SAM('TOTAL','S-I')/TABS0;
 MGOVSHR0     = SUM(C, SAM(C,'GOV'))/TABS0;
 GOVSHR0(GOVF) = SUM(C, SAM(C,'GOV')*GOVFSHR(C,GOVF))/TABS0;

 WALRAS0      = 0;

*------------------------------------------------------------------------------------------
*5. VARIABLE DECLARATIONS -------------------------------------------------------------------
*------------------------------------------------------------------------------------------
```

```
*This section only includes variables that appear in the model.
*The variables are declared in alphabetical order.

VARIABLES
  ALPHAVAADJ(A)  productivity parameter
  CPI           consumer price index (PQ-based)
  DPI           index for domestic producer prices (PDS-based)
  DMPS          change in marginal propensity to save for selected inst
  DTINS         change in domestic institution tax share
  DTQ           change in sales tax rate
  EG            total current government expenditure
  EH(H)         household consumption expenditure
  EXR           exchange rate
  FSAV          foreign savings
  GADJ(GOVF)    government demand scaling factor
  MGADJ         government demand scaling factor
  GOVSHR(GOVF)  govt consumption share of absorption by function
  MGOVSHR       govt consumption share of absorption
  GSAV          government savings
  GDEFGDP       government deficit as a percentage of GDP
  IADJ          investment scaling factor (for fixed capital formation)
  INVSHR        investment share of absorption
  MPS(INS)      marginal propensity to save for dom non-gov inst ins
  MPSADJ        savings rate scaling factor
  PA(A)         output price of activity a
  PDD(C)        demand price for com'y c produced & sold domestically
  PDS(C)        supply price for com'y c produced & sold domestically
  PE(C,R)       price of exports
  PINTA(A)      price of intermediate aggregate
  PM(C,R)       price of imports
  PQ(C)         price of composite good c
  PVA(A)        value added price
  PWE(C,R)      world price of exports
  PWM(C,R)      world price of imports
  PX(C)         average output price
  PXAC(A,C)     price of commodity c from activity a
  QA(A)         level of domestic activity
  QD(C)         quantity of domestic sales
  QE(C,R)       quantity of exports
  QF(F,A)       quantity demanded of factor f from activity a
  QFS(F)        quantity of factor supply
  QG(C,GOVF)    quantity of government consumption
  QH(C,H)       quantity consumed of marketed commodity c by household h
  QHA(A,C,H)    quantity consumed of home commodity c fr act a by hhd h
  QINT(C,A)     quantity of intermediate demand for c from activity a
  QINTA(A)      quantity of aggregate intermediate input
```

```
QINV(C)        quantity of fixed investment demand
QM(C,R)        quantity of imports
QQ(C)          quantity of composite goods supply
QT(C)          quantity of trade and transport demand for commodity c
QVA(A)         quantity of aggregate value added
QVAADJ(A)      adjustment to aggregate value added (used for projections)
QX(C)          quantity of aggregate marketed commodity output
QXAC(A,C)      quantity of ouput of commodity c from activity a
TABS           total absorption
TINS(INS)      rate of direct tax on domestic institutions ins
TINSADJ        direct tax scaling factor
TQ(C)          sales tax rate
TQADJ          sales tax scaling factor
TRII(INS,INSP) transfers to dom. inst. insdng from insdngp
WALRAS         savings-investment imbalance (should be zero)
WALRASSQR      Walras squared
WF(F)          economy-wide wage (rent) for factor f
WFREAL(F)      real wage
WFDIST(F,A)    factor wage distortion variable
YF(F)          factor income
YG             total current government income
YIF(INS,F)     income of institution ins from factor f
YI(INS)        income of (domestic non-governmental) institution ins
;

*-----------------------------------------------------------------------------------------
*6. VARIABLE DEFINITIONS -------------------------------------------------------------
*-----------------------------------------------------------------------------------------

*The initial levels of all model variables are defined in this file.
INCLUDE    C:\Users\camara\Desktop\2011 Desktop\CAADP model3\1VARINIT.INC
```

GAMS Rev 228 x86/MS Windows
File for initializing variables. Standard CGE modeling system, Version 1.00
Input file: 1dmodel.gms. IFPRI Extended standard recursive dynamic CGE modeling system, Version 2.00

Version 1.00 Release date: May 02, 2001
Last update:

```
ALPHAVAADJ.L(A) = 1;
CPI.L           = CPI0;
DMPS.L          = DMPS0;
DPI.L           = DPI0;
DTINS.L         = DTINS0;
DTQ.L           = DTQ0;
EG.L            = EG0;
EH.L(H)         = EH0(H);
EXR.L           = EXR0;
FSAV.L          = FSAV0;
GADJ.L(GOVF)    = GADJ0(GOVF);
GOVSHR.L(GOVF)  = GOVSHR0(GOVF);
MGADJ.L         = MGADJ0;
MGOVSHR.L       = MGOVSHR0;
GSAV.L          = GSAV0;
IADJ.L          = IADJ0;
INVSHR.L        = INVSHR0;
MPS.L(INSDNG)   = MPS0(INSDNG);
MPSADJ.L        = MPSADJ0;
PA.L(A)         = PA0(A);
PDD.L(C)        = PDD0(C);
PDS.L(C)        = PDS0(C);
PINTA.L(A)      = PINTA0(A) ;
PE.L(C,R)       = PE0(C,R);
PM.L(C,R)       = PM0(C,R);
PQ.L(C)         = PQ0(C);
PVA.L(A)        = PVA0(A);
PWE.L(C,R)      = PWE0(C,R);
PWM.L(C,R)      = PWM0(C,R);
PX.L(C)         = PX0(C);
PXAC.L(A,C)     = PXAC0(A,C);
QA.L(A)         = QA0(A);
QD.L(C)         = QD0(C);
QE.L(C,R)       = QE0(C,R);
QF.L(F,A)       = QF0(F,A);
QFS.L(F)        = QFS0(F);
QG.L(C,GOVF)    = QG0(C,GOVF);
QH.L(C,H)       = QH0(C,H);
```

```
 QHA.L(A,C,H)    = QHA0(A,C,H);
 QINT.L(C,A)     = QINT0(C,A);
 QINTA.L(A)      = QINTA0(A) ;
 QINV.L(C)       = QINV0(C);
 QM.L(C,R)       = QM0(C,R);
 QQ.L(C)         = QQ0(C);
 QT.L(C)         = QT0(C);
 QVA.L(A)        = QVA0(A);
 QVAADJ.L(A)     = 1;
 QX.L(C)         = QX0(C);
 QXAC.L(A,C)     = QXAC0(A,C);
 TABS.L          = TABS0;
 TRII.L(INSDNG,INSDNGP) = TRII0(INSDNG,INSDNGP);
 TINS.L(INSDNG)  = TINS0(INSDNG);
 TINSADJ.L       = TINSADJ0;
 TQ.L(C)         = TQ0(C);
 TQADJ.L         = TQADJ0;
 WALRAS.L        = WALRAS0;
 WALRASSQR.L     = 0 ;
 WF.L(F)         = WF0(F);
 WFREAL.L(F)       = WFREAL0(F);
 WFDIST.L(F,A)   = WFDIST0(F,A);
 YF.L(f)         = YF0(f);
 YG.L            = YG0;
 YI.L(INS)       = YI0(INS);
 YIF.L(INS,F)    = YIF0(INS,F);

*Optional include file that imposes lower limits for selected variables
*The inclusion of this file may improve solver performance.
*$INCLUDE 1VARLOW.INC

*---------------------------------------------------------------------------------------------
*7. EQUATION DECLARATIONS ---------------------------------------------------------------
*---------------------------------------------------------------------------------------------

EQUATIONS

*Price block ----------------------------------------------
 PMDEF(C,R)     domestic import price
 PEDEF(C,R)     domestic export price
 PDDDEF(C)      dem price for com'y c produced and sold domestically
 PQDEF(C)       value of sales in domestic market
 PXDEF(C)       value of marketed domestic output
```

```
  PADEF(A)       output price for activity a
  PINTADEF(A)    price of aggregate intermediate input
  PVADEF(A)      value-added price
  CPIDEF         consumer price index
  DPIDEF         domestic producer price index

*Production and trade block ------------------------------
  CESAGGPRD(A)    CES aggregate prod fn (if CES top nest)
  CESAGGFOC(A)    CES aggregate first-order condition (if CES top nest)
  LEOAGGINT(A)    Leontief aggreg intermed dem (if Leontief top nest)
  LEOAGGVA(A)     Leontief aggreg value-added dem (if Leontief top nest)
  CESVAPRD(A)     CES value-added production function
  QVADEF(A)       sector growth projection or adjustment factor
  CESVAFOC(F,A)   CES value-added first-order condition
  CESVAPRD2(F,A)     lower level VA function producing aggregate factor f
  CESVAFOC2(F,FP,A)  lower level VA first-order condition for producing f from fp
  INTDEM(C,A)     intermediate demand for commodity c from activity a
  COMPRDFN(A,C)   production function for commodity c and activity a
  OUTAGGFN(C)     output aggregation function
  OUTAGGFOC(A,C)  first-order condition for output aggregation function
  CET(C)          CET function
  CET2(C)         domestic sales and exports for outputs without both
  ESUPPLY(C,R)    export supply
  ARMINGTON(C)    composite commodity aggregation function
  COSTMIN(C,R)    first-order condition for composite commodity cost min
  ARMINGTON2(C)   comp supply for com's without both dom. sales and imports
  QTDEM(C)        demand for transactions (trade and transport) services
  LBRSUPPLY(F)    labor supply function
  WFREALEQ        real wage equation
  WFDEF(F)        high level wage determination
  RELWAGEQ(F)       wage convergence between skilled and highly-skilled

*Institution block ----------------------------------------
  YFDEF(F)        factor incomes
  YIFDEF(INS,F)   factor incomes to domestic institutions
*XD 2007Dec
  YI1FDEF(F)      factor incomes to domestic institutions
  YI2FDEF(F)      factor incomes to domestic institutions
  YI3FDEF(F)      factor incomes to domestic institutions
  YI4FDEF(F)      factor incomes to domestic institutions

  YIDEF(INS)      total incomes of domest non-gov't institutions
  EHDEF(H)        household consumption expenditures
  TRIIDEF(INS,INSP) transfers to inst'on ins from inst'on insp
  HMDEM(C,H)      LES cons demand by hhd h for marketed commodity c
```

```
 HADEM(A,C,H)    LES cons demand by hhd h for home commodity c fr act a
 INVDEM(C)       fixed investment demand
 GOVDEM(C,GOVF)  government consumption demand
 EGDEF           total government expenditures
 YGDEF           total government income

*System constraint block ---------------------------------
 COMEQUIL(C)     composite commodity market equilibrium
 FACEQUIL(F)     factor market equilibrium
 CURACCBAL       current account balance (of RoW)
 GOVBAL          government balance
 TINSDEF(INS)    direct tax rate for inst ins
 MPSDEF(INS)     marg prop to save for inst ins
 TQDEF(C)        sales tax adjustment equation
 SAVINVBAL       savings-investment balance
 TABSEQ          total absorption
 INVABEQ         investment share in absorption
 GDABEQ(GOVF)    government consumption share in absorption by function
 GDABEQ2         government consumption share in absorption
 OBJEQ           Objective function

 EXPRESID1(C)
 EXPRESID2(C)
 GDPEQ
 INVGDP
 GOVGDP
 PXDEF2(C)
 ICADEF(C,A)
 ICA1DEF2(C,A)
 ICA1DEF(C,A)
 ICATOTDEF(A)
;

PARAMETER
 GDP0
 INVGDPSHR0
 GOVGDPSHR0
;

VARIABLE
 GDP
 INVGDPSHR
 GOVGDPSHR
;

 GDP0 = SUM(A, PVA0(A)*QVA0(A));
```

```

 INVGDPSHR0 = (SUM(C, PQ0(C)*QINV0(C)) + SUM(C, PQ0(C)*qdst(C))) / GDP0;

 GOVGDPSHR0 = SUM((GOVF,C), PQ0(C)*QG0(C,GOVF)) / GDP0;

 GDP.L       = GDP0;
 INVGDPSHR.L = INVGDPSHR0;
 GOVGDPSHR.L = GOVGDPSHR0;

VARIABLE
 ICAVA(C,A)
 ICAVA1(C,A)
 ICATOT(A)
;

 ICAVA.L(C,A) =  ica(C,A);
 ICAVA1.L(C,A)=  ica(C,A);
 ICATOT.L(A) = 1;

*------------------------------------------------------------------------
*8. EQUATION DEFINITIONS ------------------------------------------------
*------------------------------------------------------------------------
*Notational convention inside equations:
*Parameters and "invariably" fixed variables are in lower case.
*"Variable" variables are in upper case.

*Price block ---------------------------------------------

 PMDEF(C,R)$CMR(C,R).. PM(C,R) =E= pwm(C,R)*(1 + tm(C,R))*EXR + SUM(CT, PQ(CT)*icm(CT,C));

 PEDEF(C,R)$CER(C,R).. PE(C,R) =E= pwe(C,R)*(1 - te(C,R))*EXR - SUM(CT, PQ(CT)*ice(CT,C));

 PDDDEF(C)$CD(C).. PDD(C) =E= PDS(C) + SUM(CT, PQ(CT)*icd(CT,C));

 PQDEF(C)$(CD(C) OR CM(C)).. PQ(C)*(1 - TQ(C))*QQ(C) =E= PDD(C)*QD(C) + SUM(R, PM(C,R)*QM(C,R));

 PXDEF(C)$(CX(C) AND (NOT CERES(C))).. PX(C)*QX(C) =E= PDS(C)*QD(C) + SUM(R, PE(C,R)*QE(C,R));

 PXDEF2(C)$CERES(C)..   PX(C) =E= PDS(C);

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```
PADEF(A)$PVA0(A).. PA(A) =E= SUM(C, PXAC(A,C)*theta(A,C));

* PINTADEF(A)$PVA0(A).. PINTA(A) =E= SUM(C, PQ(C)*ica(C,A)) ;
PINTADEF(A)$PVA0(A).. PINTA(A) =E= SUM(C, PQ(C)*ICAVA(C,A)) ;
* PINTADEF(A)$PVA0(A).. PINTA(A)*QINTA(A) =E= SUM(C, PQ(C)*QINT(C,A));

PVADEF(A)$PVA0(A).. PA(A)*(1-ta(A))*QA(A) =E= PVA(A)*QVA(A) +
PINTA(A)*QI
     NTA(A) ;

CPIDEF..        CPI =E= SUM(C, cwts(C)*PQ(C)) ;

* DPIDEF..        DPI =E= SUM(CD$(NOT CERES(CD)), dwts(CD)*PDS(CD)) ;
DPIDEF..        DPI =E= SUM(CD, dwts(CD)*PDS(CD)) ;

*Production and trade block -------------------------------

*CESAGGPRD and CESAGGFOC apply to activities with CES function at
*top of technology nest.

CESAGGPRD(A)$ACES(A).. QA(A) =E= alphaa(A)*(deltaa(A)*QVA(A)**(-rhoa(A))
     + (1-deltaa(A))*QINTA(A)**(-rhoa(A)))**(-1/rhoa(A)) ;

CESAGGFOC(A)$ACES(A).. QVA(A) =E=
QINTA(A)*((PINTA(A)/PVA(A))*(deltaa(A)/
      (1 - deltaa(A))))**(1/(1+rhoa(A))) ;

*LEOAGGINT and LEOAGGVA apply to activities with Leontief function at
*top of technology nest.
LEOAGGINT(A)$ALEO(A).. QINTA(A) =E= inta(A)*QA(A) ;
* LEOAGGINT(A)$ALEO(A).. PINTA(A)*QINTA(A) =E= inta(A)*PA(A)*QA(A) ;

LEOAGGVA(A)$ALEO(A).. QVA(A) =E= iva(A)*QA(A) ;

*CESVAPRD, CESVAFOC, INTDEM apply at the bottom of the technology nest
*(for all activities).
CESVAPRD(A)$QVA0(A).. QVA(A) =E=
alphava(A)*ALPHAVAADJ(A)*(SUM(F$MFA1(F,A
     ), deltava(F,A)*(fprd(F,A)*QF(F,A))**(-rhova(A))))**(-1/rhova(A)) ;

*Adjustment factor to QVA (used in fixing sector growth)
QVADEF(A)$QVA0(A).. QVA(A) =E= QVAADJ(A) * QVA0(A);

CESVAFOC(F,A)$MFA1(F,A)..
               WF(F)*wfdist(F,A) =E=
               PVA(A)*(1-tva(A)) * QVA(A)*SUM(FP, deltava(FP,A)*(fprd(FP
```

```
,A)*QF(FP,A))**(-rhova(A)))**(-1) *deltava(F,A)*fprd(F,A)**(-rhova(A))*QF(
F,A)**(-rhova(A) - 1);

CESVAPRD2(F,A)$SUM(FP, MFA2(F,FP,A))..
             QF(F,A) =E= alphava2(F,A)*(SUM(FP$MFA2(F,FP,A), deltava2(
F,FP,A)*QF(FP,A)**(-rhova2(F,A))))**(-1/rhova2(F,A)) ;

CESVAFOC2(F,FP,A)$MFA2(F,FP,A)..
             WF(FP)*wfdist(FP,A) =E=
             WF(F)*wfdist(F,A) * QF(F,A) * SUM(FPP$MFA2(F,FPP,A), delt
ava2(F,FPP,A)*QF(FPP,A)**(-rhova2(F,A)))**(-1)*deltava2(F,FP,A)*QF(FP,A)**
(-rhova2(F,A)-1);

* INTDEM(C,A)$ica(C,A).. QINT(C,A) =E= ica(C,A)*QINTA(A);
 INTDEM(C,A)$ica(C,A).. QINT(C,A) =E= ICAVA(C,A)*QINTA(A);

 ICA1DEF(C,A)$(QA0(A) AND PQ0(C) AND CSER(C))..          ICAVA1(C,A) =E=
ica(C,A) * PQ0(C)/PQ(C);
 ICA1DEF2(C,A)$(QA0(A) AND (NOT CSER(C)))..    ICAVA1(C,A) =E= ica(C,A);


 ICATOTDEF(A)$(QA0(A))..              ICATOT(A) =E= SUM(C, ICAVA1(C,A));
 ICADEF(C,A)$(QA0(A) AND PQ0(C))..     ICAVA(C,A) =E= ICAVA1(C,A) / ICATOT
(A);


 COMPRDFN(A,C)$theta(A,C).. QXAC(A,C) + SUM(H, QHA(A,C,H)) =E= theta(A,C)*
QA(A) ;

 OUTAGGFN(C)$CX(C).. QX(C) =E= alphaac(C)*SUM(A, eltaac(A,C)*QXAC(A,C)**(
-rhoac(C)))**(-1/rhoac(C));

 OUTAGGFOC(A,C)$deltaac(A,C)..
             PXAC(A,C) =E= PX(C)*QX(C) * SUM(AP, deltaac(AP,C)*QXAC(AP
,C)**(-rhoac(C)) )**(-1)*deltaac(A,C)*QXAC(A,C)**(-rhoac(C)-1);

*Ghana (sectors with residual exports instead of CET)
 CET(C)$(CE(C) AND CD(C) AND (NOT CERES(C)))..
             QX(C) =E= alphat(C)*(SUM(R, deltat(C,R)*QE(C,R)**rhot(C))
 + (1 - SUM(R, deltat(C,R)))*QD(C)**rhot(C))**(1/rhot(C)) ;

*Ghana (sectors with residual exports instead of CET)
 ESUPPLY(C,R)$(CER(C,R) AND CD(C) AND (NOT CERES(C)))..
             QE(C,R) =E=  QD(C)*((PE(C,R)/PDS(C))*((1 - SUM(RP, deltat
(C,RP)))/deltat(C,R)))**(1/(rhot(C)-1)) ;

```

```
*Ghana (sectors with residual exports instead of CET)
 EXPRESID1(C)$CERES(C).. QE(C,'ROW')  =E= QX(C) - QD(C);

 EXPRESID2(C)$CERES(C).. PDD(C) =E= PE(C,'ROW');

 CET2(C)$((CD(C) AND CEN(C)) OR (CE(C) AND CDN(C))).. QX(C) =E= QD(C) + SUM(R, QE(C,R));

 ARMINGTON(C)$(CM(C) AND CD(C))..
               QQ(C) =E= alphaq(C)*(SUM(R, deltaq(C,R)*QM(C,R)**(-rhoq(C))) + (1-SUM(R, deltaq(C,R)))*QD(C)**(-rhoq(C)))**(-1/rhoq(C));

 COSTMIN(C,R)$(CD(C) AND CMR(C,R))..
               QM(C,R)/QD(C) =E= (PDD(C)/PM(C,R)*deltaq(C,R)/(1-SUM(RP, deltaq(C,RP))))**(1/(1+rhoq(C)));

 ARMINGTON2(C)$( (CD(C) AND CMN(C)) OR (CM(C) AND CDN(C)) ).. QQ(C) =E= QD(C) + SUM(R, QM(C,R));

 QTDEM(C)$CT(C).. QT(C) =E= SUM(CP, icd(C,CP)*QD(CP)) + SUM((CP,R), icm(C,CP)*QM(CP,R)) + SUM((CP,R), ice(C,CP)*QE(CP,R));

 LBRSUPPLY(F)$(FLS(F) AND FDIS(F))..
               QFS(F) =E= QFS0(F)*[ ([SUM(A, WF(F)*WFDIST(F,A)*QF(F,A))/QFS(F)]/CPI) / (WF0(F)/CPI0)]**(etals(F));

 WFREALEQ(F)$WFREAL0(F).. WFREAL(F) =E= SUM(A, WF(F)*wfdist(F,A)*QF(F,A))/((CPI/CPI0)*SUM(A, QF(F,A))) ;

 WFDEF(F)$SUM((FP,A), MFA2(F,FP,A)).. WF(F) =E= SUM((FP,A)$MFA2(F,FP,A), WFDIST(FP,A)*WF(FP)*QF(FP,A) ) / SUM((FP,A)$MFA2(F,FP,A), QF(FP,A) );

 RELWAGEQ(F)$LREL(F).. WFREAL(F)/SUM(FP$MAPRELW(FP,F), WFREAL(FP)) =E= WFREAL0(F)/SUM(FP$MAPRELW(FP,F), WFREAL0(FP)) + CONVERGE(F);

*Institution block ----------------------------------------

 YFDEF(F)$FDIS(F).. YF(F) =E= SUM(A, WF(F)*wfdist(F,A)*QF(F,A));

*XD 2007Dec
 YI1FDEF(F)..
```

```
          YIF('hcrur',F) =E= SUM(A$(AAGR(A) and MAPAZONE(A,'zone1')), WF(F)*wfdist(F,A)*QF(F,A))
                + shifN('hcrur',F)*((1-tf(f))*YF(F) - SUM(A$AAGR(A), WF(F)*wfdist(F,A)*QF(F,A)) - trnsfr('ROW',F)*EXR) ;

 YI2FDEF(F)..
          YIF('hfrur',F) =E= SUM(A$(AAGR(A) and MAPAZONE(A,'zone2')), WF(F)*wfdist(F,A)*QF(F,A))
                + shifN('hfrur',F)*((1-tf(f))*YF(F) - SUM(A$AAGR(A), WF(F)*wfdist(F,A)*QF(F,A)) - trnsfr('ROW',F)*EXR) ;

 YI3FDEF(F)..
          YIF('hssru',F) =E= SUM(A$(AAGR(A) and MAPAZONE(A,'zone3')), WF(F)*wfdist(F,A)*QF(F,A))
               + shifN('hssru',F)*((1-tf(f))*YF(F) - SUM(A$AAGR(A), WF(F)*wfdist(F,A)*QF(F,A)) - trnsfr('ROW',F)*EXR) ;

 YI4FDEF(F)..
          YIF('hsnru',F) =E= SUM(A$(AAGR(A) and MAPAZONE(A,'zone4')), WF(F)*wfdist(F,A)*QF(F,A))
               + shifN('hsnru',F)*((1-tf(f))*YF(F) - SUM(A$AAGR(A), WF(F)*wfdist(F,A)*QF(F,A)) - trnsfr('ROW',F)*EXR) ;

* YIFDEF(INSD,F)$shif(INSD,F)..
*              YIF(INSD,F) =E= shif(INSDE,F)*((1-tf(f))*YF(F) - trnsfr('ROW',F)*EXR);

 YIFDEF(H,F)$HURB(H)..
             YIF(H,F) =E= shifN(H,F)*((1-tf(f))*YF(F) - SUM(A$AAGR(A), WF(F)*wfdist(F,A)*QF(F,A)) - trnsfr('ROW',F)*EXR);

 YIDEF(INSDNG)$YI0(INSDNG)..
             YI(INSDNG) =E=
             SUM(F, YIF(INSDNG,F))  + SUM(INSDNGP, TRII(INSDNG,INSDNGP)) + trnsfr(INSDNG,'GOV')*CPI + trnsfr(INSDNG,'ROW')*EXR;

 TRIIDEF(INSDNG,INSDNGP)$(shii(INSDNG,INSDNGP))..
             TRII(INSDNG,INSDNGP) =E= shii(INSDNG,INSDNGP) * (1 - MPS(INSDNGP)) * (1 - TINS(INSDNGP))* YI(INSDNGP);

 EHDEF(H)..      EH(H) =E= (1 - SUM(INSDNG, shii(INSDNG,H))) * (1 - MPS(H)) * (1 - TINS(H)) * YI(H);

 HMDEM(C,H)$betam(C,H)..
             PQ(C)*QH(C,H) =E=
             PQ(C)*gammam(C,H) + betam(C,H)*( EH(H) - SUM(CP, PQ(CP)*g
```

```
ammam(CP,H)) - SUM((A,CP), PXAC(A,CP)*gammah(A,CP,H))) ;

HADEM(A,C,H)$betah(A,C,H)..
               PXAC(A,C)*QHA(A,C,H) =E=
               PXAC(A,C)*gammah(A,C,H) + betah(A,C,H)*(EH(H) - SUM(CP, PQ(CP)*gammam(CP,H)) - SUM((AP,CP), PXAC(AP,CP)*gammah(AP,CP,H))) ;

INVDEM(C)$CINV(C).. QINV(C) =E= IADJ*qbarinv(C);

GOVDEM(C,GOVF).. QG(C,GOVF) =E= MGADJ*GADJ(GOVF)*qbarg(C,GOVF);

YGDEF..        YG =E= SUM(INSDNG, TINS(INSDNG)*YI(INSDNG))
               + SUM(f, tf(F)*YF(F))
               + SUM(A, tva(A)*PVA(A)*QVA(A))
               + SUM(A, ta(A)*PA(A)*QA(A))
               + SUM((CM,R), tm(CM,R)*pwm(CM,R)*QM(CM,R))*EXR
               + SUM((CE,R), te(CE,R)*pwe(CE,R)*QE(CE,R))*EXR
               + SUM(C, TQ(C)*PQ(C)*QQ(C))
               + SUM(F, YIF('GOV',F))
               + trnsfr('GOV','ROW')*EXR;

EGDEF..        EG =E= SUM((C,GOVF), PQ(C)*QG(C,GOVF)) + SUM(INSDNG, trnsfr(INSDNG,'GOV'))*CPI;


*System constraint block ----------------------------------

FACEQUIL(F)..   SUM(A, QF(F,A)) =E= QFS(F);

COMEQUIL(C)..   QQ(C) =E= SUM(A, QINT(C,A)) + SUM(H, QH(C,H)) + SUM(GOVF, QG(C,GOVF)) + QINV(C) + qdst(C) + QT(C);

CURACCBAL..     SUM((CM,R), pwm(CM,R)*QM(CM,R)) + SUM(F, trnsfr('ROW',F)) =E= SUM((CE,R), pwe(CE,R)*QE(CE,R)) + SUM(INSD, trnsfr(INSD,'ROW')) + FSAV;

GOVBAL..       YG =E= EG + GSAV;

TINSDEF(INSDNG).. TINS(INSDNG) =E= tinsbar(INSDNG)*(1 + TINSADJ*tins01(INSDNG)) + DTINS*tins01(INSDNG);

MPSDEF(INSDNG)..  MPS(INSDNG)  =E= mpsbar(INSDNG)*(1 + MPSADJ*mps01(INSDNG)) + DMPS*mps01(INSDNG);

```

```
TQDEF(C)..      TQ(C) =E= tqbar(C)*(1 + TQADJ*tq01(C)) + DTQ*tq01(C);

SAVINVBAL..     SUM(INSDNG, MPS(INSDNG) * (1 - TINS(INSDNG)) *
YI(INSDNG)
    ) + GSAV + FSAV*EXR =E=
                SUM(C, PQ(C)*QINV(C)) + SUM(C, PQ(C)*qdst(C)) + WALRAS;

TABSEQ..        TABS =E= SUM((C,H), PQ(C)*QH(C,H)) + SUM((A,C,H), PXAC(A,
    C)*QHA(A,C,H))
                + SUM((C,GOVF), PQ(C)*QG(C,GOVF)) + SUM(C, PQ(C)*QINV(C))
     + SUM(C, PQ(C)*qdst(C));

INVABEQ..       INVSHR*TABS =E= SUM(C, PQ(C)*QINV(C)) + SUM(C, PQ(C)*qdst
    (C));

GDABEQ(GOVF)..  GOVSHR(GOVF)*TABS =E= SUM(C, PQ(C)*QG(C,GOVF));

GDABEQ2..       MGOVSHR*TABS =E= SUM((C,GOVF), PQ(C)*QG(C,GOVF));

GDPEQ..         GDP =E= SUM(A, PVA(A)*QVA(A));

INVGDP..        INVGDPSHR*GDP =E= SUM(C, PQ(C)*QINV(C)) + SUM(C,
PQ(C)*qd
    st(C));

GOVGDP..        GOVGDPSHR*GDP =E= SUM((GOVF,C), PQ(C)*QG(C,GOVF));

OBJEQ..         WALRASSQR   =E= WALRAS*WALRAS ;

*---------------------------------------------------------------------------
*9. MODEL DEFINITION -----------------------------------------------------
*---------------------------------------------------------------------------

MODEL STANDCGE  standard CGE model /
*Price block (10)
 PMDEF.PM
 PEDEF.PE
 PQDEF.PQ
 PXDEF.PX
 PDDDEF.PDD
 PXDEF2
 PADEF.PA
 PINTADEF.PINTA
 PVADEF.PVA
 CPIDEF
 DPIDEF
```

```
*Production and trade block (17)
 CESAGGPRD
 CESAGGFOC
 LEOAGGINT.QINTA
 LEOAGGVA
 CESVAPRD.QVA
 QVADEF.QVAADJ
 CESVAFOC
 CESVAPRD2
 CESVAFOC2
 INTDEM.QINT
 COMPRDFN.PXAC
 OUTAGGFN.QX
 OUTAGGFOC.QXAC
 CET
 CET2
 ESUPPLY.QE
 ARMINGTON
 COSTMIN
 ARMINGTON2
 QTDEM.QT
 LBRSUPPLY
 WFREALEQ.WFREAL
 WFDEF.WF
 RELWAGEQ
*Institution block (12)
 YFDEF.YF
 YIFDEF.YIF
 YI1FDEF
 YI2FDEF
 YI3FDEF
 YI4FDEF
 YIDEF.YI
 EHDEF.EH
 TRIIDEF.TRII
 HMDEM.QH
 HADEM.QHA
 EGDEF.EG
 YGDEF.YG
 GOVDEM.QG
 GOVBAL
 INVDEM.QINV
*System-constraint block (9)
 FACEQUIL
 COMEQUIL
 CURACCBAL
```

```
TINSDEF.TINS
MPSDEF.MPS
TQDEF.TQ
SAVINVBAL.WALRAS
TABSEQ.TABS
INVABEQ
GDABEQ
GDABEQ2
*Ghana (sectors with residual exports instead of CET)
EXPRESID1
EXPRESID2
GDPEQ
INVGDP
GOVGDP
ICADEF
ICA1DEF2
ICA1DEF.ICAVA1
ICATOTDEF.ICATOT
/
;

*-----------------------------------------------------------------------
*10. FIXING VARIABLES NOT IN MODEL AT ZERO ------------------------------
*-----------------------------------------------------------------------

 ALPHAVAADJ.FX(A) = 1;
 PDD.FX(C)$(NOT CD(C)) = 0;
 PDS.FX(C)$(NOT CD(C)) = 0;
 PE.FX(C,R)$(NOT CER(C,R)) = 0;
 PM.FX(C,R)$(NOT CMR(C,R)) = 0;
 PX.FX(C)$(NOT CX(C)) = 0;
 PXAC.FX(A,C)$(NOT SAM(A,C)) = 0;
 PVA.FX(A)$(NOT PVA0(A)) = 0;
 QD.FX(C)$(NOT CD(C)) = 0;
 QE.FX(C,R)$(NOT CER(C,R)) = 0;
 QF.FX(F,A)$(NOT (MFA1(F,A) + SUM(FP, MFA2(FP,F,A)))) = 0;
 QG.FX(C,GOVF)$(NOT SAM(C,'GOV')) = 0;
 QH.FX(C,H)$(NOT SAM(C,H)) = 0;
 QHA.FX(A,C,H)$(NOT BETAH(A,C,H)) = 0;
 QINT.FX(C,A)$(NOT SAM(C,A)) = 0;
 QINV.FX(C)$(NOT CINV(C)) = 0;
 QM.FX(C,R)$(NOT CMR(C,R)) = 0;
 QQ.FX(C)$(NOT (CD(C) OR CM(C))) = 0;
 QT.FX(C)$(NOT CT(C)) = 0;
 QVA.FX(A)$(NOT QVA0(A)) = 0;
 QX.FX(C)$(NOT CX(C)) = 0;
```

```
 QXAC.FX(A,C)$(NOT SAM(A,C)) = 0;
 TRII.FX(INSDNG,INSDNGP)$(NOT SAM(INSDNG,INSDNGP)) = 0;
 WFREAL.FX(F)$(NOT WFREAL0(F)) = 0;
 YI.FX(INS)$(NOT INSD(INS)) = 0;
 YIF.FX(INS,F)$((NOT INSD(INS)) OR (NOT SAM(INS,F))) = 0;
 YI.FX(INS)$(NOT YI0(INS)) = 0;

*  PINTA.FX(A)$(NOT QINTA0(A)) = 0;
*  QINTA.FX(A)$(NOT QA0(A)) = 0;



*-----------------------------------------------------------------------
*11. MODEL CLOSURE ----------------------------------------------------
*-----------------------------------------------------------------------

```

In the simulation file, SIM.GMS, the user chooses between alternative closures. Those choices take precedence over the choices made in this file.

In the following segment, closures is selected for the base model solution in this file. The clearing variables for micro and macro constraints are as follows:

FACEQUIL - WF: for each factor, the economywide wage is the market-clearing variable in a setting with perfect factor mobility across activities.

CURACCBAL - EXR: a flexible exchange rate clears the current account of the RoW.

GOVBAL - GSAV: flexible government savings clears the government account.

SAVINVBAL - SADJ: the savings rates of domestic institutions are scaled to generate enough savings to finance exogenous investment quantities (investment-driven savings).

The CPI is the model numeraire.

```

*Factor markets ----------------

*Disaggregate factors:
 QFS.FX(FDIS)$(NOT LREL(FDIS))  = QFS0(FDIS);
 QFS.LO(F)$(FLS(F) AND FDIS(F)) = -INF;
 QFS.UP(F)$(FLS(F) AND FDIS(F)) = +INF;
```

```
 WF.LO(FDIS)        = -inf;
 WF.UP(FDIS)        = +inf;
 WFDIST.FX(FDIS,A)  = WFDIST0(FDIS,A);

parameter
chkQFS0(F)
;
chkQFS0(FDIS)$(NOT LREL(FDIS))  = QFS0(FDIS);

display chkQFS0;

*Aggregate factors:
 WF.LO(F)$SUM((FP,A), MFA2(F,FP,A))    = -inf;
 WF.UP(F)$SUM((FP,A), MFA2(F,FP,A))    = +inf;
 QFS.LO(F)$SUM((FP,A), MFA2(F,FP,A)) = -INF;
 QFS.UP(F)$SUM((FP,A), MFA2(F,FP,A)) = +INF;
 WFDIST.LO(F,A)$SUM(FP, MFA2(F,FP,A))  = -INF;
 WFDIST.UP(F,A)$SUM(FP, MFA2(F,FP,A))  = +INF;
 QF.LO(F,A)$SUM(FP, MFA2(F,FP,A))  = -INF;
 QF.UP(F,A)$SUM(FP, MFA2(F,FP,A))  = +INF;

*Current account of RoW ----------

* EXR.FX       = EXR0;
 FSAV.FX      = FSAV0;

*Import and export prices (in FCU) are fixed. A change in model
*specification is required if these prices are to be endogenous.
 PWM.FX(C,R)  = PWM0(C,R) ;
 PWE.FX(C,R)  = PWE0(C,R) ;

*Current government balance ------

 GSAV.FX     = GSAV0 ;
 TINSADJ.FX  = TINSADJ0;

 DTINS.FX    = DTINS0;
 DTQ.FX      = DTQ0;
 TQADJ.FX    = TQADJ0;
 GADJ.FX(GOVF) = GADJ0(GOVF);
* MGADJ.FX    = MGADJ0;
* GOVSHR.FX(GOVF)   = GOVSHR0(GOVF) ;
* MGOVSHR.FX  = MGOVSHR0;

*Savings-investment balance ------
```

```
 MPSADJ.FX = MPSADJ0;
 DMPS.FX   = DMPS0;
* IADJ.FX   = IADJ0;
* INVSHR.FX = INVSHR0 ;

*Numeraire price index -----------

 CPI.FX       = CPI0;
* DPI.FX       = DPI0;


*------------------------------------------------------------------------
*12. DISPLAY OF MODEL PARAMETERS AND VARIABLES ---------------------------
*------------------------------------------------------------------------

DISPLAY
*All parameters in this file and include files are displayed in
*alphabetical order.

ALPHAA   , ALPHAVA0  , ALPHAAC  , ALPHAQ    , ALPHAT    , ALPHAVA
BETAH    , BETAM     , BUDSHR   , BUDSHR2   , BUDSHRCHK , CPI0
CWTS     , CWTSCHK   , DELTAA   , DELTAAC   , DELTAQ
DELTAT   , DELTAVA   , DPI0     , DMPS0     , DTINS0    , DWTS
DWTSCHK  , EG0       , EH0      , ELASAC    , ELASCHK   , EXR0
FRISCH   , FSAV0     , GADJ0    , MGADJ0    , GAMMAH   , GAMMAM    , GOVSHR0   , MGOVSHR0
GSAV0    , IADJ0     , ICA      , ICD       , ICE       , ICM
INTA     , INVSHR0   , IVA      , LESELAS1  , LESELAS2  , MPS0
MPSADJ0  , MPSBAR    , PA0      , PDD0      , PDS0      , PE0
PINTA0   , PM0       , POP      , PQ0       , PRODELAS  , PRODELAS2
PVA0     , PWE0      , PWM0     , PX0       , PXAC0     , QA0
QBARG    , QBARG0    , QBARINV  , QD0       , QDST      , QDST0
QE0      , QF0       , QF2BASE  , QFBASE    , QFS0      , QFSBASE
QG0      , QH0       , QHA0     , QINT0     , QINTA0    , QINV0
QM0      , QQ0       , QT0      , QVA0      , QX0       , QXAC0
RHOA     , RHOAC     , RHOQ     , RHOT      , RHOVA     , SAM
SAMBALCHK, SHCTD     , SHCTE    , SHCTM     , SHIF      , SHIFCHK
SHII     , SHRHOME   , SUPERNUM , TA        , TA0
TABS0    , TAXPAR    , TE       , TE0       , TF        , TF0
THETA    , TINS0     , TINSADJ0 , TINSBAR   , TM        , TM0
TQ0      , TQ0       , TRADELAS , TRII0     , TRNSFR    , TVA
TVA0     , WALRAS0   , WF0      , WFREAL0   , WFA       , WFDIST0   , YF0
YG0      , YI0       , YIF0
;

```

```
*---------------------------------------------------------------------
*13. SOLUTION STATEMENT -----------------------------------------------
*---------------------------------------------------------------------

OPTIONS ITERLIM = 1000, LIMROW = 1500, LIMCOL = 1500, SOLPRINT=ON,
        MCP=PATH, NLP=CONOPT2 ;

```

These options are useful for debugging. When checking whether the initial data represent a solution, set LIMROW to a value greater than the number of equations and search for three asterisks in the listing file. SOLPRINT=ON provides a complete listing file. The program also has a number of display statements, so when running experiments it is usually not necessary to provide a solution print as well.

```

 STANDCGE.HOLDFIXED   = 1 ;
 STANDCGE.TOLINFREP   = .0001 ;

```

The HOLDFIXED option converts all variables which are fixed (.FX) into parameters. They are then not solved as part of the model.
The TOLINFREP parameter sets the tolerance for determinining whether initial values of variables represent a solution of the model equations. Whether these initial equation values are printed is determimed by the LIMROW option. Equations which are not satsfied to the degree TOLINFREP are printed with three asterisks next to their listing.

```

 SOLVE STANDCGE USING MCP ;

*---------------------------------------------------------------------
*14. OPTIONAL NLP MODEL DEFINITION AND SOLUTION STATEMENT ----------------
*---------------------------------------------------------------------

```

Define a model that can be solved using a nonlinear programming (NLP) solver. The model includes the equation OBJEQ which defines the variable WALRASSQR, which is the square of the Walras' Law variable, which must be zero in equilibrium.

```

MODEL NLPCGE  standard CGE model for NLP solver /
*Price block (10)
 PMDEF
 PEDEF
 PQDEF
 PXDEF
 PDDDEF
 PADEF
```

```
PINTADEF
PVADEF
CPIDEF
DPIDEF
*Production and trade block (17)
CESAGGPRD
CESAGGFOC
LEOAGGINT
LEOAGGVA
CESVAPRD
CESVAFOC
INTDEM
COMPRDFN
OUTAGGFN
OUTAGGFOC
CET
CET2
ESUPPLY
ARMINGTON
COSTMIN
ARMINGTON2
QTDEM
LBRSUPPLY
WFREALEQ
*Institution block (12)
YFDEF
YIFDEF
YIDEF
EHDEF
TRIIDEF
HMDEM
HADEM
EGDEF
YGDEF
GOVDEM
GOVBAL
INVDEM
*System-constraint block (9)
FACEQUIL
COMEQUIL
CURACCBAL
TINSDEF
MPSDEF
SAVINVBAL
TABSEQ
INVABEQ
```

```
GDABEQ
GDABEQ2
OBJEQ
GDPEQ
INVGDP
GOVGDP
/
;

NLPCGE.HOLDFIXED   = 1 ;
NLPCGE.TOLINFREP   = .0001 ;

* SOLVE NLPCGE MINIMIZING WALRASSQR USING NLP ;

*------------------------------------------------------------------------
*15. SOLUTION REPORTS ----------------------------------------------------
*------------------------------------------------------------------------

*Optional include file defining report parameters summarizing economic
*data for the base year.

```

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